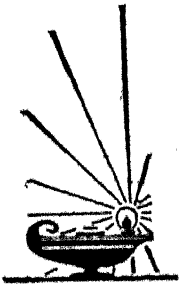
THE POCKET UNIVERSITY

SCIENCE



VOLUME I

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INTRODUCTION

It is one thing to read about the isolated processes and facts with which scientists are concerned; it is quite another to read about them in relation to the private lives of scientists themselves. It is splendid, for example, to know that Pasteur was able to save the French silk industry, but it is heroic to know that he did it in the face of sorrow and death and sickness and discouragement. It is interesting to know that the secret of making enamel was lost and rediscovered after many centuries, but much is added to the story when we know that Palissy, after years of work, poverty and disappointment finally burned his fences, his furniture, and his shelves trying to get heat intense enough to see whether what he had was what he thought he had. It is interesting to know that microscopes fine enough to show the world of microbes were first made about 250 years ago; but how much more so when we know that the first person who made one was an obscure Dutch dry-goods dealer who learned to grind lenses from the spectacle makers.

Benvenuto Cellini may seem a strange figure here, for Benvenuto was an artist, not a scien-

tist. But there are certain arts (indeed, nearly all of them) that depend upon science for their beauty, and sculpture is one of them. Not only is the story of Benvenuto's casting his great statue told, but also the story of his petty quibblings with the Duke, who turned out to be, as Benvenuto said, more of a merchant than a Duke. Thoreau also may seem a strange figure in such company, but science is based upon facts collected by first hand observation, and Thoreau was furnishing those. Other first hand field observations are given by William Beebe, W. H. Hudson and Jean Henri Fabre who severally discuss their personal acquaintance with hoatzins, bats and bees.

A glimpse into the heavens is given by one of the most patient and inspiring of teachers, M. Flammarion, the French astronomer. Half the people who look at Jupiter, he says, think they are looking at Venus, which is "a sufficiently gross error." But, he adds, "even this error is preferable to nothing. It is better to be mistaken than not to see anything. . . . To notice a star in the sky, even to give it a wrong name, is something, at all events," which might be taken as a motto by any beginner in any field: "It is better to be mistaken than not to see anything. . . . To notice a star in the sky, even to give it a wrong name, is something at all events."

ELEPHANT FRIENDS AND FOES*

I HAVE sat in the top of a tree in the middle of a herd a quarter of a mile from a native village in Uganda in a last desperate effort to inspect the two hundred and fifty elephants which had been chevying me about so fast that I had not had a chance to see whether there were any desirable specimens among them or not. I have spent a day and a night in the Budongo Forest in the middle of a herd of seven hundred elephants. I have stood on an ant-hill awaiting the rush of eleven elephants which had got my wind and were determined to get me. I have spent a day following and fighting an old bull which took twenty-five shots of our elephant rifles before he succumbed. And once also I had such close contact with an old bull up on the slopes of Mt. Kenia that I had to save myself from being gored by grabbing his tusks with my hands and swinging in between them.

I have spent many months studying elephants in Africa—on the plains, in the forests, in the

*From "In Brightest Africa" by permission from Mr. Akeley.

bamboo, up on the mountains. I have watched them in herds and singly, studied their paths, their feeding grounds, everything about them I could, and I have come to the conclusion that of all the wild animals on this earth now, the African elephant is the most fascinating, and that man, for all the thousands of years he has known of elephants, knows mighty little about him. I am speaking only of the African elephant. He has not been domesticated as his Indian cousin has. The two are different in size and different in shape and different in habits. The low point of an African elephant's back line is the highest point of that of the Indian elephant. The African elephant's ears and tusks are larger, and his tusks usually spread wider at the points instead of coming together. Unless one studies him in his native haunts, one cannot get to know him. His disposition is held to be wilder than that of the Indian elephant, but the infrequency of his appearance in circuses and in zoological parks may be attributed to the ease with which tamed elephants may be obtained from India rather than to a difference of temper in the two beasts. An African elephant at Washington and one in the Bronx zoological park are the only ones I know of in this country, and no animal in captivity can give one more than a slight idea of his natural habits in his jungle home.

Very few people have studied African ele-

phants in the field. Ninety-five per cent. of those who have followed them have been purely hunters and their desire has been, not to study, but to shoot—to see the elephant the shortest possible time. Time to judge the ivories and get a bead on the brain was all that they wanted. Of other elephant knowledge all that they needed was the simple facts of how to follow and find them. The comparatively few men who have tried to study the elephant have not gained as much knowledge as one would imagine, because without trying it one cannot realize how extremely difficult it is to study the live African elephant.

For example, as I said before, I spent a day with seven hundred elephants in the Budongo Forest, but although I heard them all the time and was very acutely conscious that they were near me, I do not believe that I actually had my eyes on an elephant more than half an hour, all told, during the day. It happened this way.

One night about dark, after a week or two of hunting, we heard the squeal of an elephant while we were sitting at dinner. A little later there were more squeals and occasional trumpeting—more and more, clearer and clearer—and by the time we had finished dinner the noise was only a mile or so away. It was a continuous row which suggested a tremendous herd. We went to bed early with elephants getting closer to camp all of the time. There is little danger of elephants

attacking a camp, and, as there is no way to study them at night, about the only thing left to do was to go to bed and get in good shape for the next day. Along about midnight Mrs. Akeley came over to my tent and said that she had loaded my guns and that they were all ready. She could not sleep; so she went out to sit by the fire. The elephants were then within a hundred yards of our tents and there was a continuous roar made up of trumpetings, squealing, and the crashing of bushes and trees.

I got up in the morning and had breakfast before daybreak. The elephants had moved on down the edge of the forest. What had been a jungle of high grass and bush the day before was trampled flat. There were at least seven hundred elephants in the herd—government officials had counted them on the previous day as they came down. I followed the trails to the edge of the forest but saw none. I started back to cross a little *nullah* (a dry water course), but felt suspicious and decided to look the situation over a little more closely. I ran up on a sloping rock and, almost under me on the other side, I saw the back of a large elephant. Over to one side there was another one, beyond that another, and then I realized that the little *nullah* through which I had planned to pass was very well sprinkled with them. I backed off and went up to a higher rock to one side. Elephants were drift-

ing into the forest from all directions. The sun was just coming up over the hills and was shining upon the forest, which sparkled in the sunlight—morning greetings to the forest people. The monkeys greeted one another with barks and coughs. Everything was waking up—it was a busy day. There was not a breath of air. I had gone back a million years; the birds were calling back and forth, the monkeys were calling to one another, a troop of chimpanzees in the open screamed, and their shouts were answered from another group inside the forest. All the forest life was awake and moving about as that huge herd of elephants, singly and in groups, flowed into the forest from the plain. There was one continuous roar of noise, all the wild life joining, but above it all were the crashing of trees and the squealing of the elephants as they moved into the forest on a front at least a mile wide. It was the biggest show I ever saw in Africa.

Then an old cow just at the edge of the forest suddenly got my wind, and wheeling about, she let out a scream. Instantly every sound ceased, everything was quiet. The monkeys, the birds—all the wild life—stopped their racket; the elephants stood still, listening and waiting. For a moment I was dazed. The thought came through my mind— "What does it all mean? Have I been dreaming?" But soon I heard the rustling of

the trees as though a great storm were coming. There was no movement of the air, but there was the sound of a wind storm going through a forest. It gradually died away, and I realized that the elephants had made it as they moved off. It was the rustling of the dry leaves on the ground under their feet and the rubbing of their bodies through the dried foliage of the forest. I never heard a noise like that made by elephants—before or since. The conditions were unique, for everything was thoroughly parched, and there had not even been a dew. Ordinarily, if there is any moisture, elephants when warned can travel through a forest without the slightest noise. In spite of their great bulk they are as silent and sometimes as hard to see in their country as a jack rabbit is in his. I remember on one occasion being so close to an old cow in the jungle that I could hear the rumbling of her stomach, and yet when she realized my presence the rumbling ceased, as it always does when they are suspicious, and she left the clump of growth she was in without my hearing a sound.

But going back to the big herd. From the time I had seen the first elephant until the last of them disappeared in the forest it had been perhaps fifteen minutes—fifteen minutes in which to see the sight of a lifetime, a thing to go to Africa a dozen times to get one glimpse of. But what did I learn about the habits of the elephant

in that fifteen minutes? A little perhaps but not much. It takes a long time and much patience to get at all intimate with old Tembo, as the Swahilis call him, on his native soil.

After the herd disappeared in the forest I watched for ten or fifteen minutes and heard the squeal of the elephants and the noise of the monkeys again. Their suspicions were over. I followed into the forest where the trails showed me that they had broken up into small bands. I followed along on the trail of one of these bands until I got a glimpse of an elephant about fifty yards ahead of me in the trail. You don't see a whole elephant in the forest. What you do see is just a glimpse of hide or tusk or trunk through the trees. And if you want to get this glimpse without disturbing him you must do your glimpsing from down the wind.

There was a little open space ahead of the group I was following. I worked around until I got to a place where I could see them as they passed through this open space. They were moving along slowly, feeding. Two or three came out into the opening, then they became suspicious and wheeled into the forest again. I followed cautiously. I had gone only a short distance when I saw a very young calf about twenty yards ahead of me. As I halted, the mother came trotting back down the trail looking for the baby. I froze to the side of a tree with my gun ready. She

came to the baby and turning, boosted it along with her trunk after the rest of the herd. I followed along after them into an opening where I found them rounded up in a patch of burned-over ground. They were milling around in a rather compact mass seemingly preparing for defence. I could not see very plainly, for a cloud of dust rose from the burned ground as they shuffled about. I stood watching them a little time and suddenly caught sight of a fine tusk—an old bull and just what I wanted for the group I was working on for the Museum of Natural History. I ran up behind a bush at the edge of the clearing and peeked through it. There, not more than twenty yards from me, was my bull, partially exposed and partially covered by the other animals. I could not get a shot at his brain as he was standing, but the foreleg on my side was forward exposing his side so that I had a good shot at his heart—a shot I had never made before. The heart is eighteen or twenty inches long and perhaps a foot up and down—a good mark in size if one's guess at its location is accurate. If you can hit an elephant's vertebræ and break his back you can kill him. You can kill him by hitting his heart, or by hitting his brain. If you hit him anywhere else you are not likely to hurt him much and the brain and heart shots are the only safe bets. I fired at his heart with both barrels and then grabbed my other gun from

the gun boy, ready for their rush, but the whole herd, including the old bull, made off in the other direction, raising a cloud of dust. I ran around and climbed an ant-hill four or five feet high to keep them in sight.

When I caught sight of them they had gone about fifty yards and had stopped. And then I *did* learn something about elephants. My old bull was down on the ground on his side. Around him were ten or twelve other elephants trying desperately with their trunks and tusks to get him on his feet again. They were doing their best to rescue their wounded comrade. They moved his great bulk fifteen or twenty feet in their efforts, but were unable to get him up. I don't know of any other big animals that will do this. I had heard stories that elephants had the chivalry to stick by their wounded and help them, but I was never sure myself until I had actually seen this instance. Some time later Major Harrison, a very experienced elephant hunter and a keen observer, told me of an even more remarkable instance that he had seen. He was shooting in the Congo and came upon four big bulls. One he killed and another he wounded. The wounded one went down but the two survivors helped him regain his feet, and with one each side helping him the three moved off. Although Major Harrison followed the rest of the day he was not able to catch up with them.

I did not see the end of their efforts to raise the bull I had shot, for those that were not helping him began to circle about with their ears out to hear anything of their enemy and with their trunks up feeling for my wind. They were moving in ever-increasing circles which threatened to envelop my ant-hill, and I beat a hasty retreat. Not long after they evidently were convinced that the bull was dead and all together they moved away. I then went to the body. He was dead, but as we approached there was a reflex action which twitched his trunk from time to time. This frightened the gun boys so that I went up and slapped the elephant's eye, the customary test, and as there was no reaction the boys were convinced. When I looked the carcass over I was disappointed to find that only one of his tusks was big and well developed. The other was smaller, and out of shape from an injury; consequently I decided not to take him for the museum group. He was, however, a good deal of a temptation, for he was one of the largest elephants I had ever seen, measuring eleven feet four inches to the top of his shoulders, and the circumference of his front foot was sixty-seven and a half inches. To the best of my knowledge this is a record size by about four inches. I did not even skin him but contented myself with taking his tusks, which I sold for nearly $500 without even going down to Nairobi.

The phenomenon of elephants helping each other when wounded is not general by any means. Only a few days after shooting the big bull I had an instance of elephants abandoning one of their number that was wounded and not very badly wounded, either.

I had gone into the forest again, and had come upon another bunch in very thick country. I could only get little glimpses of a patch of hide or ivory once in a while. After working along with them for a while in the hope of getting into more open ground I tried the experiment of beating on the tree trunks with sticks. This was new to them as it was to me. I felt sure it would make them run but I wasn't sure whether they would go toward it or away from it. Happily they bolted from the forest into the high grass, grumbling all the while. I followed as closely as I dared until finally, in hope of getting a view over the top of the high grass, I started to climb a tree. Just then they rushed back into the forest, fortunately to one side of me. I thought it was time to quit, so we started back to camp. At that moment I heard another group of elephants. They were coming out of the forest into the grass. I climbed up an ant-hill where I could see them as they passed over a ridge. There were eleven of them and not a specimen that I wanted among them. I stood watching to see what would happen next. They were about three hundred yards away when they

got my wind. Back they came, rumbling, trumpeting, and squealing. I knew that I had trouble on my hands. The only thing for me to do was to stick, for if I got down in the tall grass I couldn't see anything at all. They came up over a hill, but they were not coming straight toward me and it looked as if they would pass me at forty or fifty yards; but, unfortunately, the cow in front saw me standing in full view on my ant-hill pedestal. They turned straight at me. When the leading cow was as close as I wanted her to get—about twenty-five yards—I fired. She hesitated but again surged on with the others. A second shot knocked her down. The rest surged past her, turned, smelled of her, and ran off into the forest. After a few minutes she got upon her feet and rather groggily went off after them.

Elephants have the reputation of having very bad eyesight. I personally am of the opinion that their sight is pretty good, but on this subject, as on most others about elephants, information is neither complete nor accurate. But my experience makes me think that they can see pretty well. In this case the cow that saw me was only about fifty yards away, but at another time on the Uasin Gishu Plateau an elephant herd charged me from 250 yards with the wind from them to me. The behaviour of this particular herd gave me a clue to their reputation for bad eyesight. The elephant

is not afraid of any animal except man, and consequently he is not on the alert for moving objects as are animals that are hunted. Neither does he eat other animals, so he is not interested in their movements as a hunter. In fact, he isn't normally particularly interested in moving objects at all. He pays no attention. When we first came up with this herd on the Uasin Gishu Plateau we could move around within fifty yards of them without attracting their attention. However, after they got our wind and recognized us as enemies, they were able to see us at a distance of 250 yards, and charge us.

But however good the elephant's sight, it is nothing in comparison with his smelling ability. An elephant's trunk is probably the best smelling apparatus in the world, and he depends on his sense of smell more than on any other sense. When he is at all suspicious he moves his trunk around in every direction so that he catches the slightest taint in the air, from whichever way it comes, I have often seen elephants, when disturbed, with their trunks high in air reaching all around for my wind. I likewise, on one occasion, had an intimate view of a very quiet smelling operation by which an old cow escaped me. I was on an elephant path one day on Mt. Kenia looking for an elephant I had heard, when my gun-bearer gripped my shoulder and pointed into the forest. I looked and looked but could see nothing but the trees.

Finally I noticed that one of the trees diminished in size toward the ground and I recognized an elephant's trunk. My eyes followed it down. At the very tip it was curled back, and this curled-back part, with the nostrils distended, was moving slowly from side to side quietly fishing for my wind. She was waiting concealed beside the trail to pick me up as I came along. She was no more than forty feet away, but when she decided to give up and move away, I could not hear her going although it was a dense forest and she was accompanied by two youngsters. Very often in the forest where there is very little air stirring it is hard to tell the direction of the wind. I used to light wax taper matches as tests, for they could be struck without any noise and the flame would show the direction of the slightest breath of air.

In many other ways besides its smelling ability the elephant's trunk is the most extraordinary part of this most extraordinary animal. A man's arm has a more or less universal joint at the shoulder. The elephant's trunk is absolutely flexible at every point. It can turn in any direction and in whatever position it is, and has tremendous strength. There is no bone in it, of course, but it is constructed of interwoven muscle and sinew so tough that one can hardly cut it with a knife. An elephant can shoot a stream of water out of it that would put out a fire; lift a tree trunk weighing a ton and throw it easily; or it is delicate enough

to pull a blade of grass with. He drinks with it, feeds himself with it, smells with it, works with it, and at times fights with it. Incidentally, a mouse that endeavoured to frighten an elephant by the traditional nursery rhyme method of running up his trunk would be blown into the next county. There is nothing else like an elephant's trunk on earth.

And for that matter, there is nothing else like the elephant. He has come down to us through the ages, surviving the conditions which killed off his earlier contemporaries, and he now adapts himself perfectly to more different conditions than any other animal in Africa.

He can eat anything that is green or ever has been green, just as long as there is enough of it. He can get his water from the aloe plants on the arid plains, or dig a well in the sand of a dry river bed with his trunk and fore feet, and drink there, or he is equally at home living half in the swamps of better-watered regions. He is at home on the low, hot plains of the seacoast at the equator or on the cool slopes of Kenia and Elgon. So far as I know, he suffers from no contagious diseases and has no enemies except man. There are elephants on Kenia that have never lain down for a hundred years. Some of the plains elephants do rest lying down, but no one ever saw a Kenia elephant lying down or any evidence that he does lie down to rest. The ele-

phant is a good traveller. On good ground a good horse can outrun him, but on bad ground the horse would have no chance, and there are few animals that can cover more ground in a day than an elephant. And in spite of his appearance, he can turn with surprising agility and move through the forest as quietly as a rabbit.

An elephant's foot is almost as remarkable as his trunk. In the first place, his foot is encased in a baglike skin with a heavy padded bottom, with some of the characteristics of an anti-skid tire. An elephant walks on his toes. His toes form the front part of his foot and the bones of his foot run not only back but up. Underneath these bones at the back of his foot is a gelatine-like substance, which is a much more effective shock absorber than rubber heels or any other device. One of the curious things about this kind of a foot is that it swells out when the weight is on it and contracts when the weight is removed. As a consequence an elephant may sink four feet into a swamp but the minute he begins to lift his legs, his feet will contract and come out of the hole they have made without suction. The elephant's leg, being practically a perpendicular shaft, requires less muscular effort for him to stand than it does for ordinary animals. This is one of the reasons why he can go for a century without lying down.

A country that elephants have long inhabited

takes on some of the particular interest of the animals themselves. I believe that before the white man came to East Africa the elephant was nearly as much a plains animal as a forest animal, but he now tends to stay in the forests where the risk is not so great. On the plains there are no elephant paths now, if there ever were, for in open country elephants do not go in single file. But in the forests there are elephant paths everywhere. In fact, if it were not for the elephant paths travel in the forest would be almost impossible, and above the forests in the bamboo country this is equally true. One travels practically all the time on their trails and they go everywhere except in the tree ferns. Tree fern patches are not very extensive, but I have never seen an elephant track or an elephant in them. The elephants are constantly changing the paths for various reasons; among others, because the natives are in the habit of digging elephant pits in the trails. But there are some trails that have evidently been used for centuries. One time we had followed a band of elephants on the Aberdare Plateau and had devilled them until they began to travel away. We followed until the trail led through a pass in the mountains and we realized that they were going into a different region altogether. That trail in the pass was a little wider than an elephant's foot and worn six inches deep in the solid rock. It must have taken

hundreds of years for the shuffling of elephants to wear that rock away.

At another place on Kenia I found an elephant passage of a stream where the trail was twenty feet wide. Single paths came in from many directions on one side of the stream and joined in this great boulevard, which crossed the stream and broke up again on the other side into the single paths radiating again in every direction. In many places where the topography of the ground is such that there is only one place for a trail there will be unmistakable evidence that the trails have stayed in the same place many years—such as trees rubbed half in two by the constant passing of the animals or damp rocks polished by the caress of their trunks. And along all the trails, old and new, are elephant signs, footprints, dung, and gobs of chewed wood and bark from which they have extracted the juices before spitting them out.

But finding the elephants is not so frequent or easy as the multiplicity of the signs would indicate. One reason is that the signs of elephants—tracks, rubbed trees, and so forth—are more or less enduring, many of them being very plain in places where the elephants have not been for months or even years. If, however, you come on fresh elephant tracks, not more than a day old, you can usually catch up with the elephants, for as they feed along through the country they do

not go fast. Only if they are making a *trek* from one region to another it may take much longer to catch them.

Once up with an elephant, if you are shooting, you are pretty sure that, even if he is charging you, a bullet from an elephant gun, hitting him in the head, will stop him even if it does not hit him in a vital spot. Moreover, if you stop the leader of a bunch that is charging you, the bunch will stop. I never heard of a case in which the leader of an elephant charge was stopped and the others kept on, and I doubt if we ever will hear of such a thing, for if it does happen there won't be any one to tell about it. It is unusual for an elephant to keep on after being hit even if the hit does not knock him down. The old cow that charged me at the head of ten others was rather the exception to this rule, for after my first shot stopped her she came on again until my second shot knocked her down. But I had one experience that was entirely at variance with this rule. One old bull took thirteen shots from my rifle and about as many from Mrs. Akeley's before he was content either to die or run away.

In Uganda, after six months in the up-country after elephants, we decided to go down to the Uasin Gishu Plateau for lion spearing, for the rainy season was beginning and the vegetation growing so thick that elephant hunting was getting very difficult. On the way down we came one

morning upon the fresh trail of a herd of elephants. We followed for about two hours in a high bush country over which were scattered clumps of trees. Finally we came upon the elephants at the time of their mid-day siesta. The middle of the day is the quietest time of the twenty-four hours with elephants. If they are in a herd, they will bunch together in the shade. They do not stand absolutely still, but mill about very slowly, changing positions in the bunch but not leaving. They are neither feeding nor travelling but, as nearly as they ever do, resting. I even saw a young bull once rest his tusks in the crotch of a tree during this resting period. We got up to within twenty-five yards of them behind some bushes down the wind. We finally decided upon one of the bulls as the target. Mrs. Akeley studied carefully and shot. The bull went down, apparently dead. Ordinarily, we should rush in for a finishing shot, but in this case the rest of the herd did not make off promptly, so we stood still. When they did go off we started toward the apparently dead animal. As we did so, he got upon his feet and, in spite of a volley from us, kept on after the herd. We followed, and after half an hour's travel we caught sight of him again. We kept along behind him, looking for a place where we could swing out to one side and get abreast to fire a finishing shot at him. He was moving slowly and groggily. It was hard to move

anywhere except in his trail without making a noise, and I suddenly discovered that the trail was turning so that the wind was from us to him.

Immediately we swung off to one side, but it was too late. I didn't see him when he got our wind but I knew perfectly he had it for there was the sudden crash of his wheel in the bushes and a scream. An elephant's scream is loud and shrill and piercing. And it is terrifying, too—at least to any one who knows elephants—for it means an angry animal and usually a charge. Then came a series of grunts and rumblings. A second or two later he came in sight, his ears spread out twelve feet from tip to tip, his trunk up and jerking fiercely from side to side. There is no way of describing how big an elephant looks under these conditions, or the speed at which he comes. At about thirty yards I shot, but he took it. He stopped, seemingly puzzled but unhurt. I shot the second barrel and looked for my other gun which was thirty feet behind me. The boy ran up with it and I emptied both barrels into the elephant's head, and still he took it like a sand hill. In the meanwhile, Mrs. Akeley had been firing, too. And then he turned and went off again. I went back to Mrs. Akeley. Everything that I knew about elephant shooting had failed to apply in this case. I had stopped him with one shot. That

was normal enough. But then I had put three carefully aimed shots into his head at short range, any one of which should have killed him. And he had taken them with only a slight flinch and then had gone off. I felt completely helpless. Turning to Mrs. Akeley, I said:

"This elephant is pretty well shot up, and perhaps we had better wait for developments."

She said: "No, we started it; so let's finish it."

I agreed as we reloaded, and we were about to start following when his screaming, grunting, roaring attack began again. Exactly the same thing happened as the first time except that this time Mrs. Akeley, the boy, and I were all together. We fired as we had before. He stopped with the first shot and took all the others standing, finally turning and retreating again. Apparently our shots had no effect except to make him stop and think. I was sick of it, for maybe next time he wouldn't stop and evidently we couldn't knock him down. We had about finished reloading when we heard him once more. There was nothing to do but stand the charge, for to run was fatal. So we waited. There was an appreciable time when I could hear his onrush but couldn't see him. Then I caught sight of him. He wasn't coming straight for us, but was charging at a point thirty yards to one side of us and thrashing back and forth a great branch of tree in his trunk. Why his charge was so mis-

directed I didn't know, but I was profoundly grateful. As he ran I had a good brain shot from the side. I fired, and he fell stone dead. With the greatest sense of relief in the world I went over to him. As I stood by the carcass I felt very small indeed. Mrs. Akeley sat down and drew a long breath before she spoke.

"I want to go home," she said at last, "and keep house for the rest of my life."

Then I heard a commotion in the bush in front of the dead elephant and as I looked up a black boy carrying a cringing monkey appeared. Only the boy wasn't black. He was scared to an ashen colour and he was still trembling, and the monkey was as frightened as the boy. It was J. T. Jr., Mrs. Akeley's pet monkey, and Alli, the monkey's nurse. They had followed to see the sport without our knowledge, and they had drawn the elephant's last charge.

This experience with an animal that continued to make charge after charge was new to me. It has never happened again and I hope never will, but it shows that with elephants it isn't safe to depend on any fixed rule, for elephants vary as much as people do. This one was the heaviest-skulled elephant I ever saw, and the shots that I had fired would have killed any ordinary animal. But in his case all but the last shot had been stopped by bone.

I couldn't measure his height, but I measured

his ear as one indication of his size. It was the biggest I ever heard of. And his tusks were good sized—80 pounds. He was a very big animal, but his foot measurement was not so large as the big bull of the Budongo Forest. Later I made a dining table of his ear, supporting it on three tusks for legs. With the wooden border it was eight feet long and seated eight people very comfortably.

Most wild animals, if they smell man and have an opportunity to get away, make the most of it. Even a mother with young will usually try to escape trouble rather than bring it on, although, of course, they are quickest to fight. But elephants are not always in this category. In the open it has been my experience that they would rather leave than provoke a fight; if you hunt elephants in the forest, you are quite likely to find that two can play the hunting game, and find yourself pretty actively hunted by the elephants. If the elephants after you are making a noise, it gives you a good chance. When they silently wait for you, the game is much more dangerous.

The old bull, who is in the centre of the elephant group in the Museum of Natural History now, tried to get me by this silent method. I was out on a trail and I saw that a big bunch of animals were near. I wasn't following any particular trail for they had moved about so that

signs were everywhere and much confused. Finally I came to a gully. It wasn't very broad or very deep, but the trail I was on turned up it to where a crossing could be made on the level. The forest here was high and very thick, and consequently it was quite dark. As I looked up the trail I saw a group of big shapes through the branches. I thought they were elephants and peered carefully at them, but they turned out to be boulders. A minute later I saw across the gully another similar group of boulders, but as I peered at them I saw through a little opening in the leaves, plain and unmistakable, an elephant's tusk. I watched it carefully. It moved a little, and behind it I caught a glimpse of the other tusk. They were big, and I decided that he would do for my group. I couldn't get a glimpse of his eye or anything to sight by, so I carefully calculated where his brain ought to be from the place where his tusk entered his head, and fired. Then there was the riot of an elephant herd suddenly starting. A few seconds later there was a crash. "He's down," I thought, and Bill, the gun boy, and I ran over to the place where the animals had been. We followed their tracks a little way and found where one of the elephants had been down, but he had recovered and gone on. However, he had evidently gone off by himself when he got up, for while the others had gone down an old trail he had gone

straight through the jungle, breaking a new way as he went. With Bill in the lead, we pushed along behind him. It was a curious trail, for it went straight ahead without deviation as if it had been laid by compass. One hour went by and then another. We had settled down for a long *trek*. The going wasn't very good and the forest was so thick that we could not see in any direction. We were pushing along in this fashion when, with a crash and a squeal, an elephant burst across our path within fifteen feet of us. It was absolutely without warning, and had the charge been straight on us we could hardly have escaped. As it was, I fired two hurried shots as he disappeared in the growth on the opposite side of the trail. The old devil had grown tired of being hunted and had doubled back on his own trail to wait for us. He had been absolutely silent. We hadn't heard a thing, and his plan failed, I think, only because the growth was so thick that he charged us on scent or sound without being able to see us. I heard him go through the forest a way and then stop. I followed until I found a place a little more open than the rest, and with this between me and the trees he was in I waited. I could hear him grumbling in there from time to time. I didn't expect him to last much longer so I got my lunch and ate it while I listened and watched. I had just finished and had a puff or two on

my pipe when he let out another squeal and charged. He evidently had moved around until he had wind of me. I didn't see him but I heard him, and grabbing the gun I stood ready. But he didn't come. Instead I heard the breaking of the bushes as he collapsed. His last effort had been too much for him.

The efforts of the next elephant who tried the quiet waiting game on me were almost too much for me.

We had just come down from the ice fields seventeen thousand feet up on the summit of Mt. Kenia, overlord of the game regions of British East Africa, and had come out of the forest directly south of the pinnacle and within two or three miles of an old camping ground in the temperate climate, five or six thousand feet above sea level, where we had camped five years before and again one year before. Instead of going on around toward the west to the base camp we decided to stop here and have the base camp brought up to us. Mrs. Akeley was tired, so she said she would stay at the camp and rest; and I decided to take advantage of the time it would take to bring up the base camp to go back into the bamboo and get some forest photographs.

There was perfectly good elephant country around our camp but I wanted to go back up where the forests stop and the bamboo flourishes, because it was a bamboo setting that I had

selected for the group of elephants I was then working on for the African Hall in the American Museum of Natural History. I started out with four days' rations, gun boys, porters, camera men, and so forth—fifteen men in all. The second day out brought me to about nine thousand feet above sea level where the bamboo began. Following a well-worn elephant trail in search of this photographic material, I ran on to a trail of three old bulls. The tracks were old—probably as much as four days—but the size was so unusual that I decided to postpone the photography and follow them. I did not expect to have to catch up their four days' travel, for I hoped that they would be feeding in the neighbourhood and that the trail I was on would cross a fresher trail made in their wanderings around for food. I had run upon their tracks first about noon. I followed until dark without finding any fresher signs. The next morning we started out at daybreak and finally entered an opening such as elephants use as a feeding ground. It is their custom to mill around in these openings, eating the vegetation and trampling it down until it offers little more, and then move on. In six months or so it will be grown up again eight or ten feet high and they are very apt to revisit it and go through the same process again. Soon after we entered this opening I came suddenly upon fresh tracks of the elephants I had been

following. Not only were the tracks fresh but the droppings were still steaming and I knew that the animals were not far away; certainly they had been there not more than an hour before. I followed the trail amongst the low bush in the opening but it merely wandered about repeatedly bringing me back to the place where I had first seen the fresh tracks, and I realized that I might do this indefinitely without getting closer to the elephants. I decided to go outside the opening and circle around it to see if I could find the trail of my bulls as they entered the forest. This opening was at the point on the mountain where the forest proper and the bamboos merged. I followed an elephant path out of the opening on the bamboo side and had gone but a little way when I discovered fresh signs of my three bulls, who had evidently left the opening by the same path that I was following, and at about the same time I heard the crackling of bamboo ahead, probably about two hundred yards away. This was the signal for preparation for the final stalk.

I stood for a moment watching one of the trackers going up the trail to a point where it turned at right angles in the direction of the sounds I had heard. There he stopped at rest, having indicated to me by signs that they had gone in that direction. I turned my back to the trail, watching the porters select a place to lay

down their loads amidst a clump of large trees that would afford some protection in case of a stampede in their direction. The gun boys came forward presenting the guns for inspection. I took the gun from the second boy, sending him back with the porters. After examining this gun I gave it to the first boy and took his. When I had examined this I leaned it against my body while I chafed my hands which were numb from the cold mists of the morning, knowing that I might soon need a supple trigger finger. During this time the first gun boy was taking the cartridges, one by one, from his bandoleer and holding them up for my inspection—the ordinary precaution to insure that all the ammunition was the right kind, and an important insurance, because only a full steel-jacketed bullet will penetrate an elephant's head. While still warming my hands, inspecting the cartridges, and standing with the gun leaning against my stomach, I was suddenly conscious that an elephant was almost on top of me. I have no knowledge of how the warning came. I have no mental record of hearing him, seeing him, or of any warning from the gun boy who faced me and who must have seen the elephant as he came down on me from behind. There must have been some definite signal, but it was not recorded in my mind. I only know that as I picked up my gun and wheeled about I tried to shove the safety catch

forward. It refused to budge, and I remember the thought that perhaps I had left the catch forward when I inspected the gun and that if not I must pull the triggers hard enough to fire the gun anyway. This is an impossibility, but I remember distinctly the determination to do it, for the all-powerful impulse in my mind was that I must shoot instantly. Then something happened that dazed me. I don't know whether I shot or not. My next mental record is of a tusk right at my chest. I grabbed it with my left hand, the other one with my right hand, and swinging in between them went to the ground on my back. This swinging in between the tusks was purely automatic. It was the result of many a time on the trails imagining myself caught by an elephant's rush and planning what I would do, and a very profitable planning, too; for I am convinced that if a man imagines such a crisis and plans what he would do, he will, when the occasion occurs, automatically do what he planned. Anyway, I firmly believe that my imaginings along the trail saved my life.

He drove his tusks into the ground on either side of me, his curled-up trunk against my chest. I had a realization that I was being crushed, and as I looked into one wicked little eye above me I knew I could expect no mercy from it. This thought was perfectly clear and definite

in my mind. I heard a wheezy grunt as he plunged down and then—oblivion.

The thing that dazed me was a blow from the elephant's trunk as he swung it down to curl it back out of harm's way. It broke my nose and tore my cheek open to the teeth. Had it been an intentional blow it would have killed me instantly. The part of the trunk that scraped off most of my face was the heavy bristles on the knuckle-like corrugations of the skin of the under side.

When he surged down on me, his big tusks evidently struck something in the ground that stopped them. Of course my body offered practically no resistance to his weight, and I should have been crushed as thin as a wafer if his tusks hadn't met that resistance—stone, root, or something—underground. He seems to have thought me dead for he left me—by some good fortune not stepping on me—and charged off after the boys. I never got much information out of the boys as to what did happen, for they were not proud of their part in the adventure. However, there were plenty of signs that the elephant had run out into the open space again and charged all over it; so it is reasonable to assume that they had scattered through it like a covey of quail and that he had trampled it down trying to find the men whose tracks and wind filled the neighbourhood.

Usually, when an elephant kills a man, it will return to its victim and gore him again, or trample him, or pull his legs or arms off with its trunk. I knew of one case where a man's porters brought in his arm which the elephant that had killed him had pulled off his body and left lying on the ground. In my case, happily, the elephant for some reason did not come back. I lay unconscious for four or five hours. In the meanwhile, when they found the coast was clear, the porters and gun boys returned and made camp, intending, no doubt, to keep guard over my body until Mrs. Akeley, to whom they had sent word, could reach me. They did not, however, touch me, for they believed that I was dead, and neither the Swahili Mohammedans nor the Kikuyus will touch a dead man. So they built a fire and huddled around it and I lay unconscious in the cold mountain rain at a little distance, with my body crushed and my face torn open. About five o'clock I came to in a dazed way and was vaguely conscious of seeing a fire. I shouted, and a little later I felt myself being carried by the shoulders and legs. Later again I had a lucid spell and realized that I was lying in one of the porter's tents, and I got clarity of mind enough to ask where my wife was. The boys answered that she was back in camp. That brought the events back to me, how I had left her at camp, found the trail of the three old

bulls, followed them and, finally, how I was knocked out. I was entirely helpless. I could move neither my arms nor legs and I reached the conclusion that my back was broken. I could not move, but I felt no pain whatever. However, my coldness and numbness brought to my mind a bottle of cocktails, and I ordered one of the boys to bring it to me. My powers of resistance must have been very low, for he poured all there was in the bottle down my throat. In the intervals of consciousness, also, I got them to give me hot bovril—a British beef tea—and quinine. The result of all this was that the cold and numbness left me. I moved my arms. The movement brought pain, but I evidently wasn't entirely paralyzed. I moved my toes, then my feet, then my legs. "Why," I thought in some surprise, "my back isn't broken at all!" So before I dropped off again for the night I knew that I had some chance of recovery. The first time I regained consciousness in the morning, I felt that Mrs. Akeley was around. I asked the boys if she had come. They said no, and I told them to fire my gun every fifteen minutes. Then I dropped off into unconsciousness again and awoke to see her sitting by me on the ground.

When the elephant got me, the boys had sent two runners to tell Mrs. Akeley. They arrived about six in the evening. It was our custom when separated to send notes to each other, or

at least messages. When these boys came on to say that an elephant had got me, and when she found that there was no word from me, it looked bad. Mrs. Akeley sent word to the nearest government post for a doctor and started her preparations to come to me that night. She had to go after her guides, even into the huts of a native village, for they did not want to start at night. Finally, about midnight, she got under way. She pushed along with all speed until about daybreak, when the guides confessed that they were lost. At this juncture she was sitting on a log, trying to think what to do next. And then she heard my gun. She answered, but it was more than an hour before the sounds of her smaller rifle reached our camp. And about an hour after the boys heard her gun she arrived.

She asked me how I was, and I said that I was all right. I noticed a peculiar expression on her face. If I had had a looking glass, I should probably have understood it better. One eye was closed and the forehead over it skinned. My nose was broken and my cheek cut so that it hung down, exposing my teeth. I was dirty all over, and from time to time spit blood from the hemorrhages inside. Altogether, I was an unlovely subject and looked hardly worth saving. But I did get entirely over it all, although it took me three months in bed. The thing that was serious was that the elephant had crushed

several of my ribs into my lungs, and these internal injuries took a long time to heal. As a matter of fact, I don't suppose I would have pulled through even with Mrs. Akeley's care if it hadn't been for a Scotch medical missionary who nearly ran himself to death coming to my rescue. He had been in the country only a little while and perhaps this explains his coming so fast when news reached him of a man who had been mauled by an elephant. The chief medical officer at Fort Hall, knowing better what elephant mauling usually meant, came, but he didn't hurry. I saw him later and he apologized, but I felt no grievance. I understood the situation. Usually when an elephant gets a man a doctor can't do anything for him.

But this isn't always so. Some months later I sat down in the hotel at Nairobi with three other men, who like myself had been caught by elephants and had lived to tell the tale. An elephant caught Black in his trunk, and threw him into a bush that broke his fall. The elephant followed him and stepped on him, the bush this time forming a cushion that saved him, and although the elephant returned two or three times to give him a final punch, he was not killed. However, he was badly broken up.

Outram and a companion approached an elephant that was shot and down, when the animal suddenly rose, grabbed Outram in his trunk and

threw him. The elephant followed him, but Outram scrambled into the grass while the elephant trampled his pith helmet into the ground, whereupon Outram got right under the elephant's tail and stuck to this position while the elephant turned circles trying to find him, until, becoming faint from his injuries, Outram dived into the grass at one side. Outram's companion by this time got back into the game and killed the elephant.

Hutchinson's story I have forgotten a little now, but I remember that he said the elephant caught him, brushed the ground with him, and then threw him. The elephant followed him and Hutchinson put off fate a few seconds by somehow getting amongst the elephant's legs. The respite was enough, for the gun boy, by this time, began firing and drove the elephant off.

In all of these cases, unlike mine, the elephants had used their trunks to pick up their victims and to throw them, and they had intended finishing them by trampling on them. This use of the trunk seems more common than the charge with the tusks that had so nearly finished me. Up in Somaliland Dudo Muhammud, my gun boy, showed me the spot where he had seen an elephant kill an Italian prince. The elephant picked the prince up in his trunk and beat him against his tusks, the prince, meanwhile, futilely beating the elephant's head with his fists.

Then the elephant threw him upon the ground, walked on him, and then squatted on him, rubbing back and forth until he had rubbed his body into the ground.

But elephants do use their tusks and use them with terrible effect. About the time we were in the Budongo Forest, Mr. and Mrs. Longdon were across Lake Albert in the Belgian Congo. One day Longdon shot a bull elephant and stood watching the herd disappear, when a cow came down from behind, unheard and unseen, ran her tusk clear through him and, with a toss of her head, threw him into the bush and went on. Longdon lived four days.

But although the elephant is a terrible fighter in his own defence when attacked by man, that is not his chief characteristic. The things that stick in my mind are his sagacity, his versatility, and a certain comradeship which I have never noticed to the same degree in other animals. I like to think of the picture of the two old bulls helping along their comrade wounded by Major Harrison's gun; to think of several instances I have seen of a phenomenon, which I am sure is not accidental, when the young and husky elephants formed the outer ring of a group protecting the older ones from the scented danger. I like to think back to the day I saw the group of baby elephants playing with a great ball of

baked dirt two and a half feet in diameter which, in their playing, they rolled for more than half a mile, and the playfulness with which this same group teased the babies of a herd of buffalo until the cow buffaloes chased them off. I think, too, of the extraordinary fact that I have never heard or seen African elephants fighting each other. They have no enemy but man and are at peace amongst themselves.

It is my friend the elephant that I hope to perpetuate in the central group in the Roosevelt African Hall as it is now planned for the American Museum of Natural History—a hall with groups of African animal skins mounted on sculptured bodies, with backgrounds painted from the country itself. In this, which we hope will be an everlasting monument to the Africa that was, the Africa that is now fast disappearing, I hope to place the elephant group on a pedestal in the centre of the hall—the rightful place for the first animal of them all.

And it may not be many years before such museum exhibits are the only remaining records of my jungle friends. As civilization advances in Africa, the extinction of the elephant is being accomplished slowly but quite as surely as that of the American buffalo two generations ago. It is probably not true that the African elephant cannot be domesticated. In fact, somewhere in

the Congo is a farm where fifty tame elephants, just as amenable as those in India, are at work. But taming elephants is not a sound proposition economically. Elephant farming is a prince's game, and Africa has no princes to play it. An elephant requires hundreds of acres of land, infinitely more than cattle and sheep and the other domesticated animals. So it is that as man moves on the land, the elephant must move off.

Moreover, African settlers are making every effort to hasten the process. Wherever the elephants refuse to be confined to their bailiwicks and annoy the natives by raiding their farms, the Government has appointed official elephant killers. The South African elephant in the Addoo bush was condemned to be exterminated several years ago. Here, however, the hunters sent into the bush to kill them off found the elephant too much for them and finally gave up the attempt. Now they are being shot only as they come out to molest the natives, with the result that they are able to persist in the bush in limited numbers. Uganda also has official elephant killers wherever the elephants make trouble in the natives' gardens. In British East Africa and in Tanganyika a similar situation exists. The game must eventually disappear as the country is settled, and with it will be wiped out the charm of Africa.

We had heard much of Ruindi Plains in the

Belgian Congo as the wonderful game country that it no doubt used to be. To me it seems a vast graveyard. There, too, commercialism has played its part in exterminating the animals and, while we found two or three species of antelope and many lions, other large game is very rare. I suppose that the Ruindi Valley was discovered among the last of the great game pockets and that ivory poachers are responsible for the disappearance of much of the other game as well as of the elephant. The forested valley, which I went through for perhaps ten miles, carried every evidence of having been a wonderful game country in the past, but only a pitiful remnant of the splendid animals who once made it their home remains. Along great elephant boulevards, all overgrown, weaving through the forest, one may occasionally track a single elephant or a small band. A small herd of buffalo grazes where a few years ago there were great numbers.

In our journey north from Cape Town by rail we saw not a single head of game until we reached the Lualaba River, and during the five days that we spent going down that river we saw only a few antelope, perhaps a half dozen elephants and, as I remember it, two or three hippopotami. On the entire journey to within fifty miles of Lake Edward and in all our hunting we found signs of only a few small bands

of elephants. Men have spoken of darkest Africa, but the dark chapters of African history are only now being written by the inroads of civilization.

CARL AKELEY.

THE REDISCOVERY OF ENAMEL

THOUGH the art of making common vessels of clay was known to most of the ancient nations, that of manufacturing enameled earthenware was much less common. It was, however, practiced by the ancient Etruscans, specimens of whose ware are still to be found in antiquarian collections. But it became a lost art, and was only recovered at a comparatively recent date. The Etruscan ware was very valuable in ancient times, a vase being worth its weight in gold in the time of Augustus. The Moors seemed to have preserved among them a knowledge of the art, which they were found practising in the island of Majorca when it was taken by the Pisans in 1115. Among the spoil carried away were many plates of Moorish earthenware, which, in token of triumph, were imbedded in the walls of several of the ancient churches of Pisa, where they are to be seen to this day. About two centuries later the Italians began to make an imitation enameled ware, which they named Majolica, after the Moorish place of manufacture.

The reviver or re-discoverer of the art of enameling in Italy was Luca della Robbia, a

Florentine sculptor. Vasari describes him as a man of indefatigable perseverance, working with his chisel all day and practising drawing during the greater part of the night. He pursued the latter art with so much assiduity, that when working late, to prevent his feet from freezing with the cold, he was accustomed to provide himself with a basket of shavings, in which he placed them to keep himself warm and enable him to proceed with his drawings. "Nor," says Vasari, "am I in the least astonished at this, since no man ever becomes distinguished in any art whatsoever who does not early begin to acquire the power of supporting heat, cold, hunger, thirst, and other discomforts; whereas those persons deceive themselves altogether who suppose that when taking their ease and surrounded by all the enjoyments of the world they may still attain to honourable distinction—for it is not by sleeping, but by waking, watching and labouring continually, that proficiency is attained and reputation acquired."

But Luca, notwithstanding all his application and industry, did not succeed in earning enough money by sculpture to enable him to live by the art, and the idea occurred to him that he might nevertheless be able to pursue his modeling in some material more facile and less dear than marble. Hence it was that he began to make his models in clay, and to endeavour by experi-

ment so to coat and bake the clay as to render those models durable. After many trials he at length discovered a method of covering the clay with a material, which, when exposed to the intense heat of a furnace, became converted into an almost imperishable enamel. He afterward made the further discovery of a method of imparting colour to the enamel, thus greatly adding to its beauty.

The fame of Luca's work extended throughout Europe, and specimens of his art became widely diffused. Many of them were sent into France and Spain, where they were greatly prized. At that time coarse brown jars and pipkins were almost the only articles of earthenware produced in France; and this continued to be the case, with comparatively small improvement, until the time of Palissy—a man who toiled and fought against stupendous difficulties with a heroism that sheds a glow almost of romance over the events of his checkered life.

Bernard Palissy is supposed to have been born in the south of France, in the diocese of Agen, about the year 1510. His father was probably a worker in glass, to which trade Bernard was brought up. His parents were poor people—too poor to give him the benefit of any school education. "I had no other books," said he afterward, "than heaven and earth, which are open to all." He learned, however, the art of glass-

painting, to which he added that of drawing, and afterward reading and writing.

When about eighteen years old, the glass trade becoming decayed, Palissy left his father's house, with his wallet on his back, and went out into the world to search whether there was any place in it for him. He first travelled toward Gascony, working at his trade where he could find employment, and occasionally occupying part of his time in land-measuring. Then he travelled northward, sojourning for various periods at different places in France, Flanders, and Lower Germany.

Thus Palissy occupied about ten more years of his life, after which he married, and ceased from his wanderings, settling down to practice glass-painting and land-measuring at the small town of Saintes, in the Lower Charente. Three children were born to him; and not only his responsibilities but his expenses increased, while, do what he could, his earnings remained too small for his needs. It was therefore necessary for him to bestir himself. Probably he felt capable of better things than drudging in an employment so precarious as glass-painting; and hence he was induced to turn his attention to the kindred art of painting and enamelling earthenware. Yet on this subject he was wholly ignorant; for he had never seen earth baked before he began his operations. He had therefore everything to learn

by himself, without any helper. But he was full of hope, eager to learn, of unbounded perseverance and inexhaustible patience.

It was the sight of an elegant cup of Italian manufacture—most probably one of Luca della Robbia's make—which first set Palissy a thinking about the new art. A circumstance so apparently insignificant would have produced no effect upon an ordinary mind, or even upon Palissy himself at an ordinary time; but occurring as it did when he was meditating a change of calling, he at once became inflamed with the desire of imitating it. The sight of this cup disturbed his whole existence; and the determination to discover the enamel with which it was glazed thenceforward possessed him like a passion. Had he been a single man he might have travelled into Italy in search of the secret; but he was bound to his wife and his children, and could not leave them; so he remained by their side groping in the dark, in the hope of finding out the process by making and enamelling earthenware.

At first he could merely guess the materials of which the enamel was composed, and he proceeded to try all manner of experiments to ascertain what they really were. He pounded all the substances which he supposed were likely to produce it. Then he bought common earthen pots, broke them into pieces, and, spreading his compounds over them, subjected them to the heat

of a furnace which he erected for the purpose of baking them. His experiments failed; and the results were broken pots and a waste of fuel, drugs, time and labour. Women do not readily sympathize with experiments whose only tangible effect is to dissipate the means of buying clothes and food for their children; and Palissy's wife, however dutiful in other respects, could not be reconciled to the purchase of more earthen pots, which seemed to her to be bought only to be broken. Yet she must needs submit; for Palissy had become thoroughly possessed by the determination to master the secret of the enamel, and would not leave it alone.

For many successive months and years Palissy pursued his experiments. The first furnace having proved a failure, he proceeded to erect another out of doors. There he burnt more wood, spoiled more drugs and pots, and lost more time, until poverty stared him and his family in the face. "Thus," said he, "I fooled away several years, with sorrow and sighs, because I could not at all arrive at my intention." In the intervals of his experiments he occasionally worked at his former callings—painting on glass, drawing portraits and measuring land; but his earnings from these sources were very small. At length he was no longer able to carry on his experiments in his own furnace because of the heavy cost of fuel; but he bought more potsherds,

broke them up as before into three or four hundred pieces, and, covering them with chemicals, carried them to a tile-work a league and a half distant from Saintes, there to be baked in an ordinary furnace. After the operation he went to see the pieces taken out; and, to his dismay, the whole of the experiments were failures. But though disappointed, he was not yet defeated; for he determined on the very spot to "begin afresh."

His business as a land-measurer called him away for a brief season from the pursuit of his experiments. In conformity with an edict of the State, it became necessary to survey the salt-marshes in the neighbourhood of Saintes for the purpose of levying the land-tax. Palissy was employed to make this survey, and prepare the requisite map. The work occupied him some time, and he was doubtless well paid for it; but no sooner was it completed than he proceeded, with redoubled zeal, to follow up his old investigations "in the track of the enamels." He began by breaking three dozen new earthen pots, the pieces of which he covered with different materials which he had compounded, and then took them to a neighbouring glass-furnace to be baked. The results gave him a glimmer of hope. The greater heat of the glass-furnace had melted some of the compounds; but though Palissy searched diligently for the white enamel he could find none.

For two more years he went on experimenting

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without any satisfactory result, until the proceeds of his survey of the salt-marshes having become nearly spent, he was reduced to poverty again. But he resolved to make a last great effort; and he began by breaking more pots than ever. More than three hundred pieces of pottery covered with his compounds were sent to the glass-furnace; and thither he himself went to watch the results of the baking. Four hours passed, during which he watched; and then the furnace was opened. The material on *one* only of the three hundred pieces of potsherd had melted, and it was taken out cool. As it hardened, it grew white—white and polished! The piece of potsherd was covered with white enamel, described by Palissy as "singularly beautiful!" And beautiful it must no doubt have been in his eyes after all his weary waiting. He ran home with it to his wife, feeling himself, as he expressed it, quite a new creature. But the prize was not yet won—far from it. The partial success of this intended last effort merely had the effect of luring him on to a succession of further experiments and failures.

In order that he might complete the invention, which he now believed to be at hand, he resolved to build for himself a glass-furnace near his dwelling, where he might carry on his operations in secret. He proceeded to build the furnace with

his own hands, carrying the bricks from the brick-field upon his back. He was bricklayer, labourer and all. From seven to eight more months passed. At last the furnace was built and ready for use. Palissy had in the meantime fashioned a number of vessels of clay in readiness for the laying on of the enamel. After being subjected to a preliminary process of baking, they were covered with the enamel compound, and again placed in the furnace for the grand crucial experiment. Although his means were nearly exhausted, Palissy had been for some time accumulating a great store of fuel for the final effort, and he thought it was enough. At last the fire was lit, and the operation proceeded. All day he sat by the furnace, feeding it with fuel. He sat there watching and feeding all through the long night. But the enamel did not melt. The sun rose upon his labours. His wife brought him a portion of the scanty morning meal—for he would not stir from the furnace, into which he continued from time to time to heave more fuel. The second day passed, and still the enamel did not melt. The sun set, and another night passed. The pale, haggard, unshorn, baffled yet not beaten Palissy sat by his furnace eagerly looking for the melting of the enamel. A third day and night passed—a fourth, a fifth, and even a sixth—yes, for six long days and nights

did the unconquerable Palissy watch and toil, fighting against hope; and still the enamel would not melt.

It then occurred to him that there might be some defect in the materials for the enamel—perhaps something wanting in the flux; so he set to work to pound and compound fresh materials for a new experiment. Thus two or three more weeks passed. But how to buy more pots?—for those which he had made with his own hands for the purposes of the first experiment were by long baking irretrievably spoiled for the purposes of a second. His money was now all spent; but he could borrow. His character was still good, though his wife and the neighbours thought him foolishly wasting his means in futile experiments. Nevertheless he succeeded. He borrowed sufficient from a friend to enable him to buy more fuel and more pots, and he was again ready for a further experiment. The pots were covered with the new compound, placed in the furnace, and the fire was again lit.

It was the last and most desperate experiment of the whole. The fire blazed up; the heat became intense; but still the enamel did not melt. The fuel began to run short! How to keep up the fire? There were the garden palings: these would burn. They must be sacrificed rather than that the great experiment should fail. The garden palings were pulled up and cast into the fur-

nace. They were burnt in vain! The enamel had not yet melted. Ten minutes more heat might do it. Fuel must be had at whatever cost. There remained the household furniture and shelving. A crashing noise was heard in the house, and amid the screams of his wife and children, who now feared Palissy's reason was giving away, the tables were seized, broken up, and heaved into the furnace. The enamel had not melted yet! There remained the shelving. Another noise of the wrenching of timber was heard within the house, and the shelves were torn down and hurled after the furniture into the fire. Wife and children then rushed from the house, and went frantically through the town, calling out that poor Palissy had gone mad, and was breaking up his very furniture for firewood! For an entire month his shirt had not been off his back, and he was utterly worn out—wasted with toil, anxiety, watching, and want of food. He was in debt, and seemed on the verge of ruin. But he had at length mastered the secret; for the last great burst of heat had melted the enamel. The common brown household jars, when taken out of the furnace after it had become cool, were found covered with a white glaze! For this he could endure reproach, contumely and scorn, and wait patiently for the opportunity of putting his discovery into practice as better days came round.

Palissy next hired a potter to make some earthen vessels after the designs which he furnished; while he himself proceeded to model some medallions in clay for the purpose of enamelling them. But how to maintain himself and his family until the wares were made and ready for sale? Fortunately there remained one man in Saintes who still believed in the integrity, if not in the judgment, of Palissy—an inn-keeper, who agreed to feed and lodge him for six months, while he went on with his manufacture. As for the working potter whom he had hired, Palissy soon found that he could not pay him the stipulated wages. Having already stripped his dwelling, he could but strip himself; and he accordingly parted with some of his clothes to the potter, in part payment of the wages which he owed him.

Palissy next erected an improved furnace but he was so unfortunate as to build part of the inside with flints. When it was heated these flints cracked and burst, and the spiculæ were scattered over the pieces of pottery, sticking to them. Though the enamel came out right, the work was irretrievably spoiled, and thus six more months' labour was lost. Persons were found willing to buy the articles at a low price, notwithstanding the injury they had sustained; but Palissy would not sell them, considering that to have done so would to be "decry and abase his honour"; and

so he broke in pieces the entire batch. "Nevertheless," says he, "hope continued to inspire me, and I held on manfully; sometimes, when visitors called, I entertained them with pleasantry, while I was really sad at heart. . . . Worst of all the sufferings I had to endure, were the mockeries and persecutions of those of my own household, who were so unreasonable as to expect me to execute work without the means of doing so. For years my furnaces were without any covering or protection, and while attending them I have been for nights at the mercy of the wind and the rain, without help or consolation, save it might be the wailing of cats on the one side and the howling of dogs on the other. Sometimes the tempest would beat so furiously against the furnaces that I was compelled to leave them and seek shelter within doors. Drenched by rain, and in no better plight than if I had been dragged through mire, I have gone to lie down at midnight or at daybreak, stumbling into the house without a light, and reeling from one side to another as if I had been drunken, but really weary with watching and filled with sorrow at the loss of my labour after such long toiling. But alas! my home proved no refuge; for, drenched and besmeared as I was, I found in my chamber a second persecution worse than the first, which makes me even now marvel that I was not utterly consumed by my many sorrows."

At this stage of his affairs, Palissy became melancholy and almost hopeless, and seems to have all but broken down. He wandered gloomily about the fields near Saintes, his clothes hanging in tatters, and himself worn to a skeleton. In a curious passage in his writings he describes how the calves of his legs had disappeared, and were no longer able with the help of garters to hold up his stockings, which fell about his heels when he walked. His family continued to reproach him for his recklessness, and his neighbours cried shame upon him for his obstinate folly. So he returned for a time to his former calling; and after about a year's diligent labour, during which he earned bread for his household and somewhat recovered his character among his neighbours, he again resumed his darling enterprise. But though he had already spent about ten years in the search for the enamel, it cost him nearly eight more years of experimental plodding before he perfected his invention. He gradually learned dexterity and certainty of result by experience, gathering practical knowledge out of many failures. Every mishap was a fresh lesson to him, teaching him something new about the nature of enamels, the qualities of argillaceous earths, the tempering of clays, and the construction and management of furnaces.

At last, after sixteen years' labour, Palissy took heart, and called himself Potter. These

sixteen years had been his term of apprenticeship to the art, during which he had wholly to teach himself, beginning at the very beginning. He was now able to sell his wares and thereby maintain his family in comfort. But he never rested satisfied with what he had accomplished. He proceeded from one step of improvement to another; always aiming at the greatest perfection possible. He studied natural objects for patterns, and with such success that the great Buffon spoke of him as "so great a naturalist as Nature only can produce." His ornamental pieces are now regarded as rare gems in the cabinets of virtuosi, and sell at almost fabulous prices. The ornaments on them are for the most part accurate models from life, of wild animals, lizards and plants, found in the fields about Saintes, and tastefully combined ornaments into the texture of a plate or vase. When Palissy had reached the height of his art he styled himself "Ouvrier de Terre et Inventeur des Rustics Figulines."

We have not, however, come to an end of the sufferings of Palissy, respecting which a few words remain to be said. Being a Protestant at a time when religious persecution waxed hot in the south of France, and expressing his views without fear, he was regarded as a dangerous heretic. His enemies having informed against him, his house at Saintes was entered by the officers of "justice," and his work-shop was thrown open

to the rabble, who entered and smashed his pottery, while he himself was hurried off by night and cast into a dungeon at Bordeaux, to wait his turn at the stake or the scaffold. He was condemned to be burnt, but a powerful noble, the Constable de Montmorency, interposed to save his life—not because he had any special regard for Palissy or his religion, but because no other artist could be found capable of executing the enamelled pavement for his magnificent château then in course of erection at Ecouen, about four leagues from Paris. By his influence an edict was issued appointing Palissy Inventor of Rustic Figulines to the King and to the Constable, which had the effect of immediately removing him from the jurisdiction of Bordeaux. He was accordingly liberated, and returned to his home at Saintes only to find it devastated and broken up. His work-shop was open to the sky, and his works lay in ruins. Shaking the dust of Saintes from his feet he left the place never to return to it, and removed to Paris to carry on the works ordered of him by the Constable and the Queen-Mother, being lodged in the Tuileries while so occupied.

Besides carrying on the manufacture of pottery, with the aid of his two sons, Palissy, during the latter part of his life, wrote and published several books on the potter's art, with a view to the instruction of his countrymen, and in order that they might avoid the many mistakes which he

himself had made. He also wrote on agriculture, on fortification, and natural history, on which latter subject he even delivered lectures to a limited number of persons. He waged war against astrology, alchemy, witchcraft, and like impostures. This stirred up against him many enemies, who pointed the finger at him as a heretic, and he was again arrested for his religion and imprisoned in the Bastille. He was now an old man of seventy-eight, trembling on the verge of the grave, but his spirit was as brave as ever. He was threatened with death unless he recanted; but he was as obstinate in holding to his religion as he had been in hunting out the secret of the enamel. The king, Henry III, even went to see him in prison to induce him to abjure his faith. "My good man," said the king, "you have now served my mother and myself for forty-five years. We have put up with your adhering to your religion amidst fires and massacres: now I am so pressed by the Guise party, as well as by my own people, that I am constrained to leave you in the hands of your enemies, and to-morrow you will be burnt unless you become converted." "Sire," answered the unconquerable old man, "I am ready to give my life for the glory of God. You have said many times that you have pity on me; and now I have pity on you, who have pronounced the words *I am constrained!* It is not spoken like a king; it is what you, and those who constrain

you, the Guisards and all your people, can never effect upon me, for I know how to die." Palissy did indeed die shortly after, a martyr, though not at the stake. He died in the Bastille, after enduring a year's imprisonment—there peacefully terminating a life distinguished for heroic labour, extraordinary endurance, inflexible rectitude, and the exhibition of many rare and noble virtues.

SAMUEL SMILES.

THE PLANET MARS*

THE inhabitants of the Earth are at last beginning to take some interest in the sky. Tired of living as blind strangers to their own country, they are beginning to know that the world on which they move about is a planet gravitating round the Sun, and that other sister-planets swing round at the same time in the harmony of the solar system. Mars is now spoken of in public as one speaks of politics and of socialism. In America as well as in Europe, at Buenos Ayres, Mexico, or Caracas, as well as at Paris, Milan, Petrograd, Budapest, and Stockholm, the latest telescopic results are discussed. It is known that this neighbouring planet sometimes approaches the Earth within 37½ or even 35 million miles; that astronomers have their eyes on the planet and that they have observed luminous flashes on it, the explanation of which is puzzling them. People remember that in a certain year, 1877, the planet being in its greatest proximity, straight lines resembling canals were discovered, and that the question of possible in-

*From "Dreams of An Astronomer" by permission of and arrangement with D. Appleton & Co., N. Y.

habitants of this new country and future communication with them has been raised. Questions are put and answers are given, discussions give rise to curious confusions and exaggerations, but the net result is that an interest is created in these high questions which raise us above the vulgarities of ordinary life, and a general knowledge of the universe is advanced. That is the main thing.

The last occasions on which Mars was in close proximity to us were 1897, 1899, and 1909.

The remarkable development of public curiosity is easily explained by the marvellous achievements of contemporary astronomy and the admirable precision of certain results obtained. Unless one has a stone instead of a heart and a lump of fat in the place of a brain, it is difficult not to feel some emotion over the achievements of science. If we declare, for instance, that we know the general geography of Mars better than we do that of our own planet, the listener or reader is at first inclined to be somewhat sceptical. But if we show him, either in a telescope or in a diagram, the snows of the north or south poles of Mars, he will admit that nobody has as yet had a complete view of these regions on the Earth, in spite of the discoveries of polar explorers, and he will be convinced that we do know those Martian regions better than our own poles. That

is already a fact of some interest; but we can go farther than that.

It is not only the pole, but the whole surrounding country that is better known on the Earth, not only from the geographical, but also from the meteorological point of view. Thus, for instance, we can almost constantly measure the extent of the polar snows, and we find that it varies with the seasons. We see with our own eyes the melting of these snows taking place very rapidly under the light and heat of the Sun, night after night, so to speak, during a summer which is twice as long as ours. The snows disappear almost entirely, and only a little ice remains on a region which we know, and which represents the pole of extreme cold, situated 212 miles from the geographical pole. In spite of the perseverance and heroism of arctic explorers, none of these climatological facts have been witnessed on Earth. It is possible that the Martians are ignorant of their own phenomena if they have been unable to reach their poles. Still, since their poles are free at the end of the summer, they are much better able than we to explore their polar regions. We may say that in general the meteorology and climatology of Mars are better known than those of the Earth. At the time when you read these lines you do not know, and nobody can tell you, what sort of weather

you will have to-morrow. But we do know almost certainly what the weather will be to-morrow, next week, next month, on such and such a region on Mars: if we do not wait till the winter comes, we know that it will be fine. Hardly do we see a cloud between the vernal equinox and the autumnal equinox, neither in the equatorial nor the temperate regions, and hardly even in the circumpolar regions. If we are unable to make a drawing of the telescopic image of the planet, the difficulty hardly ever arises from the Martian atmosphere, but from our own, which is so often overcast or turbid. All the geographical configurations, seas, rivers, plains, covered with vegetation according to the moisture available, water-courses varying with the seasons, canals and oases, are mapped out with precision; we know in advance which country will pass across the field of our telescope; and the period of rotation, as already mentioned, is known to the 100th of a second. It is 24 hours 37 minutes 22.58 seconds. We also know that the Martian year contains 59,355,041 seconds, i. e. 686 terrestrial days 23 hours 30 minutes 41 seconds. But since that planet turns on its axis a little more slowly than the Earth, there are only 668 Martian days in the Martian year. In fact the Martian calendar is composed of two successive years of 668 days and a leap year of 669 days. As in our case, there is no exact number of days in the Martian year. Per-

haps their calendar has also been reformed several times without being made perfect. But let us hope that they are not as stupid as we, with our months of 28, 29, 30, and 31 days, and calling the ninth, tenth, eleventh, and twelfth month the seventh, eighth, ninth, and tenth respectively; with our disagreement about dates, Russia only arriving at the 1st of January when the rest of the civilized world has reached the 14th; with our three kinds of days: the civil day which commences at midnight, the astronomical day which commences the next midday, and the naval day which commences the previous midday; we who waited thousands of years before we could fix an exact hour, because we counted from conventional meridians, and the various countries could not agree upon the single meridian. Being probably more advanced than ourselves in its planetary age, Martian humanity is most likely more reasonable and is not mixed up with the littleness of frontiers, dialects, customs, national rivalries, etc. For a long time already, no doubt they form a simple unit. One may also suppose that they do not celebrate their new-year festival and its rejoicings amid the winter frosts, but in the hopeful days of the equinox.

. . . . . .

One of the most curious observations which have been made on this neighbouring planet, or rather which have, apart from the canals,

attracted the greatest attention, is that of the luminous flashes. It has been said that these flashes are all seen at the edge of the disc, or beyond it. This is not correct; they show themselves on the line which separates the hemisphere illuminated by the Sun from the dark hemisphere—the line called the "terminator." They are only seen when the globe of Mars offers a sensible phase, and only along the line of that terminator.

The phenomenon is a slight projection, swelling, or puffing-up of the terminator. It is not a more extraordinary observation than that of the irregularities in the lunar diameter at certain phases: the Sun illuminates, either before its rising or before its setting, the summits of mountains whose bases are still in darkness, and such summits sometimes appear on the Moon as luminous points detached from the disc. Some fertile imaginations have interpreted these flashes as forests on fire or as signals sent out by the Martians. This is going too far. But the possibility of the population of Mars by a human species more intelligent than ours is quite a natural conclusion from the observations. One may also guess without scientific heresy that the canals of Mars are rivers straightened with a deliberate intention of distributing water which has become a rarity over that planet. The astronomers who deny these possibilities show a very poor spirit. But, on the other hand, there is no reason to see nothing on

that world but human activity. Among several explanations of observed phenomena one must always prefer the simplest. In the case of luminous flashes on the terminator, the illumination of mountain-tops or clouds by the Sun suffices to account for them.

Doubts were raised concerning this explanation by the height of 200,000 feet found by an astronomer for the elevation of these mountains. I went over the calculation and found only 15,000 feet. These mountains would not therefore be higher than Mont Blanc, and perhaps less. We should also remember that those luminous projections appear every time that the planet returns to the same condition of illumination with regard to the Earth. They were observed in 1890, 1892, 1894, 1899, 1907, 1909, 1911, 1913, etc. The regions where they appear are a sort of island called Noachis, another called Hesperia, and a third called Tempe. According to all appearances, we have to do with high mountains covered with snow and with still higher clouds.

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The epoch at which the inhabitants of Mars can communicate with us has not yet arrived, or perhaps it has already passed away. All cosmological studies agree in presenting this planet as older than ours, since it is farther from the Sun, and as having passed through its phases of astral life more rapidly than we, on account of its

smallness and lightness. We cannot pretend to know the forms which living beings may have assumed there; but we cannot imagine, on the other hand, that the forces of nature, being the same as here and exercised under almost identical conditions (atmosphere, climate, seasons, water, vapours, etc.), have been sterilized by a perpetual miracle of annihilation while on Earth the cup of life overflows all round and the generative force of living beings everywhere surpasses continual and permanent production. But whatever may be the forms of Martian humanity, they must be superior to us, for several reasons. The first of these is that it would be difficult for a human species to be less intelligent than ours, because we do not know how to behave and three-quarters of our resources are employed for feeding soldiers.

The second reason is that progress is an absolute law which nothing can resist. If therefore, the inhabitants of Mars have passed their infancy, the centuries have brought them to an age of reason, and their present state represents what our race will be in several million years.

A third circumstance is that they are better situated than ourselves for escaping from the heaviness of matter. A given bulk of water, earth, or other substance is only seven-tenths of the weight it is here; 1,000 grammes taken to Mars would only weigh 376 grammes there; and the

woman weighing 8 stone would only weigh 3 stone there.

And, finally, the climatic conditions appear to be much more agreeable there.

. . . . . .

Those are all advantages in favour of the Martians. If, therefore, the idea has occurred to them to make signals to us, it is probably not at the present time. There is no reason that they should think of it at the same time as we and should wait for us. Perhaps they tried 200,000 or 300,000 years ago, before the appearance of man, at the time of the cave-bear or the mammoth. Perhaps they addressed themselves to our planet at the time of the Iguanodon and the Dinosaurus. Perhaps they tried again 2,000 or 3,000 years ago. Never having seen any sign of life, they will have concluded that either there are no inhabitants on the Earth, or that they are busy with other things besides the study of the universe and eternal truths. That was true yesterday—and it is true to-day.

CAMILLE FLAMMARION.

THE Duke of Florence at this time, which was the month of August, 1545, had retired to Poggio a Cajano, ten miles distant from Florence. Thither then I went to pay him my respects, with the sole object of acting as duty required, first because I was a Florentine, and next because my forefathers had always been adherents of the Medicean party, and I yielded to none of them in affection for this Duke Cosimo. As I have said, then, I rode to Poggio with the sole object of paying my respects, and with no intention of accepting service under him, as God, who does all things well, did then appoint for me.

When I was introduced, the Duke received me very kindly; then he and the Duchess put questions concerning the works which I had executed for the King.* I answered willingly and in detail. After listening to my story, he answered that he had heard as much, and that I spoke the truth. Then he assumed a tone of sympathy, and added: "How small a recompense for such great and noble masterpieces! Friend Benvenuto, if you feel

*This Duchess was Eleonora di Toledo, well known to us through Bronzino's portrait.

inclined to execute something for me, too, I am ready to pay you far better than that King of yours has done, for whom your excellent nature prompts you to speak so gratefully." When I understood his drift, I described the deep obligations under which I lay to his Majesty, who first obtained my liberation from that iniquitous prison, and afterwards supplied me with the means of carrying out more admirable works than any artist of my quality had ever had the chance to do. While I was thus speaking, my lord the Duke writhed on his chair, and seemed as though he could not bear to hear me to the end. Then, when I had concluded, he rejoined: "If you are disposed to work for me, I will treat you in a way that will astonish you, provided the fruits of your labours give me satisfaction, of which I have no doubt." I, poor unhappy mortal, burning with desire to show the noble school * of Florence that, after leaving her in youth, I had practised other branches of the art than she imagined, gave answer to the Duke that I would willingly erect for him in marble or on bronze a mighty statue on his fine piazza. He replied that, for a first essay, he should like me to produce a Perseus; he had long set his heart on having such a monument, and he begged me to begin a model for

* This school was the Collegio dei Maestri di Belle Arti in Florence, who had hitherto known of Cellini mainly as a goldsmith.

the same.* I very gladly set myself to the task, and in a few weeks I finished my model, which was about a cubit high, in yellow wax and very delicately finished in all its details. I had made it with the most thorough study and art.†

The Duke returned to Florence, but several days passed before I had an opportunity of showing my model. It seemed indeed as though he had never set eyes on me or spoken with me, and this caused me to augur ill of my future dealings with his Excellency. Later on, however, one day after dinner, I took it to his wardrobe, where he came to inspect it with the Duchess and a few gentlemen of the court. No sooner had he seen it than he expressed much pleasure, and extolled it to the skies; wherefrom I gathered some hope that he might really be a connoisseur of art. After having well considered it for some time, always with greater satisfaction, he began

* Cosimo chose the subject of Perseus because it symbolized his own victory over the Gorgon of tyrannicide and Republican partisanship. Donatello's Judith, symbolizing justifiable regicide, and Michelangelo's David, symbolizing the might of innocent right against an overbearing usurper, already decorated the Florentine piazza. Until late, both of these masterpieces stood together there with the Perseus of Cellini.

† This is probably the precious model now existing in the Bargello Palace at Florence, in many points more interesting than the completed bronze statue under the Loggia de' Lanzi.

as follows: "If you could only execute this little model, Benvenuto, with the same perfection on a large scale, it would be the finest piece in the piazza." I replied: "Most excellent my lord, upon the piazza are now standing works by the great Donatello and the incomparable Michelangelo, the two greatest men who have ever lived since the days of the ancients.* But since your Excellency encourages my model with such praise, I feel the heart to execute it at least thrice as well in bronze." † No slight dispute arose upon this declaration; the Duke protesting that he understood these matters perfectly, and was quite aware what could be done. I rejoined that my achievements would resolve his dubitations and debates; I was absolutely sure of being able to perform far more than I had promised for his Excellency, but that he must give me means for carrying my work out, else I could not fulfil my undertaking. In return for this his Excellency bade me formulate my demands in a petition, detailing all my requirements; he would see them liberally attended to.

It is certain that if I had been cunning enough to secure by contract all I wanted for my work, I should not have incurred the great troubles which

* Donatello's Judith and Holofernes; Michelangelo's David.

† It is difficult to give the exact sense of *pertanto* and *perche* in the text but I think the drift of the sentence is rendered above.

came upon me through my own fault. But he showed the strongest desire to have the work done, and the most perfect willingness to arrange preliminaries. I therefore, not discerning that he was more a merchant than a duke, dealt very frankly with his Excellency, just as if I had to do with a prince, and not with a commercial man. I sent in my petition, to which he replied in large and ample terms. The memorandum ran as follows: "Most rare and excellent my patron, petitions of any validity and compacts between us of any value do not rest upon words or writings; the whole point is that I should succeed in my work according to my promise; and if I so succeed, I feel convinced that your most illustrious Excellency will very well remember what you have engaged to do for me." This language so charmed the Duke both with my ways of acting and of speaking that he and the Duchess began to treat me with extraordinary marks of favour.

Being now inflamed with a great desire to begin working, I told his Excellency that I had need of a house where I could instal myself and erect furnaces, in order to commence operations in clay and bronze, and also, according to their separate requirements, in gold and silver. I knew that he was well aware how thoroughly I could serve him in those several branches, and I required some dwelling fitted for my business. In

order that his Excellency might perceive how earnestly I wished to work for him, I had already chosen a convenient house, in a quarter much to my liking.* As I did not want to trench upon his Excellency for money or anything of that sort, I had brought with me from France two jewels, with which I begged him to purchase me the house, and to keep them until I earned it with my labour. These jewels were excellently executed by my workmen, after my own designs. When he had inspected them with minute attention, he uttered these spirited words, which clothed my soul with a false hope: "Take back your jewels, Benvenuto! I want you, and not them; you shall have your house free of charges." After this, he signed a rescript underneath the petition I had drawn up, and which I have always preserved among my papers. The rescript ran as follows: *"Let the house be seen to, and who is the vendor, and at what price; for we wish to comply with Benvenuto's request."* † I naturally thought that this would secure me in possession of the house; being over and above convinced that my performances must far exceed what I promised.

* This house is in the Via del Rosaio, entered from Via della Pergola, No. 6527.

† The petition and the rescript are in existence, and confirm Cellini's veracity in this transaction. See Bianchi, p. 587.

. . . While the workshop for executing my Perseus was in building, I used to work in a ground-floor room. Here I modelled the statue in plaster, giving it the same dimensions as the bronze was meant to have, and intended to cast it from this mould. But finding that it would take rather long to carry it out in this way, I resolved upon another expedient, especially as now a wretched little studio had been erected, brick on brick, so miserably built that the mere recollection of it gives me pain. So then I began the figure of Medusa, and constructed the skeleton in iron. Afterwards I put on the clay, and when that was modelled, baked it.

I had no assistants except some little shop-boys, among whom was one of great beauty; he was the son of a prostitute called La Gambetta. I made use of the lad as a model, for the only books which teach this art are the natural human body. Meanwhile, as I could not do everything alone, I looked about for workmen in order to put the business quickly through; but I was unable to find any. There were indeed some in Florence who would willingly have come, but Bandinello prevented them, and after keeping me in want of aid awhile, told the Duke that I was trying to entice his workpeople because I was quite incapable of setting up so great a statue by myself. I complained to the Duke of the annoyance which the brute gave me, and begged him

to allow me some of the labourers from the Opera.* My request inclined him to lend ear to Bandinello's calumnies; and when I noticed that, I set about to do my utmost by myself alone. The labour was enormous: I had to strain every muscle night and day; and just then the husband of my sister sickened, and died after a few days' illness. He left my sister, still young, with six girls of all ages, on my hands. This was the first great trial I endured in Florence, to be made the father and guardian of such a distressed family.

In my anxiety that nothing should go wrong, I sent for two hand-labourers to clear my garden of rubbish. They came from Ponte Vecchio, the one an old man of sixty years, the other a young fellow of eighteen. After employing them about three days, the lad told me that the old man would not work, and that I had better send him away, since, besides being idle, he prevented his comrade from working. The little I had to do there could be done by himself, without throwing money away on other people. The youth was called Bernardino Mannellini, of Muguello. When I saw that he was so inclined to labour, I asked whether he would enter my service, and

*That is, the Opera del Duomo, or permanent establishment for attending to the fabric of the Florentine Cathedral.

we agreed upon the spot. He groomed my horse, gardened, and soon essayed to help me in the workshop, with such success that by degrees he learned the art quite nicely. I never had a better assistant than he proved. Having made up my mind to accomplish the whole affair with this man's aid, I now let the Duke know that Bandinello was lying, and that I could get on famously without his workpeople.

The first piece I cast in bronze was that great bust, * the portrait of his Excellency, which I had modelled in the goldsmith's workroom while suffering from those pains in my back. It gave much pleasure when it was completed, though my sole object in making it was to obtain experience of clays suitable for bronze-casting. I was of course aware that the admirable sculptor Donatello had cast his bronzes with the clay of Florence; yet it seemed to me that he had met with enormous difficulties in their execution. As I thought that this was due to some fault in the earth, I wanted to make these first experiments before I undertook my Perseus. From them I learned that the clay was good enough, but had not been well understood by Donatello, inasmuch as I could see that his pieces had been cast with the very greatest trouble. Accordingly, as I have described above, I prepared the earth by artificial

* Now in the Museum of the Bargello Palace at Florence.

methods, and found it serve me well, and with it I cast the bust; but since I had not yet constructed my own furnace, I employed that of Maestro Zanobi di Pagno, a bell-founder.

When I saw that this bust came out sharp and clean, I set at once to construct a little furnace in the workshop erected for me by the Duke, after my own plans and design, in the house which the Duke had given me. No sooner was the furnace ready than I went to work with all diligence upon the casting of Medusa, that is, the woman twisted in a heap beneath the feet of Perseus. It was an extremely difficult task, and I was anxious to observe all the niceties of art which I had learned, so as not to lapse into some error. The first cast I took in my furnace succeeded in the superlative degree, and was so clean that my friends thought I should not need to retouch it. It is true that certain Germans and Frenchmen, who vaunt the possession of marvellous secrets, pretend that they can cast bronzes without retouching them; but this is really nonsense, because the bronze, when it has first been cast, ought to be worked over and beaten in with hammers and chisels, according to the manner of the ancients and also to that of the moderns—I mean such moderns as have known how to work in bronze.

The result of this casting greatly pleased his Excellency, who often came to my house to in-

spect it, encouraging me by the interest he showed to do my best. The furious envy of Bandinello, however, who kept always whispering in the Duke's ears, had such effect that he made him believe my first successes with a single figure or two proved nothing; I should never be able to put the whole large piece together, since I was new to the craft, and his Excellency ought to take good heed he did not throw his money away. These insinuations operated so efficiently upon the Duke's illustrious ears, that part of my allowance for workpeople was withdrawn.

I now stayed at home, and went rarely to the palace, labouring with great diligence to complete my statue. I had to pay the workmen out of my own pocket; for the Duke, after giving Lattanzio Gorini orders to discharge their wages, at the end of about eighteen months, grew tired, and withdrew this subsidy. I asked Lattanzio why he did not pay me as usual. The man replied, gesticulating with those spidery hands of his, in a shrill gnat's voice: "Why do not you finish your work? One thinks that you will never get it done." In a rage I up and answered: "May the plague catch you and all who dare to think I shall not finish it!"

So I went home with despair at heart to my unlucky Perseus, not without weeping, when I remembered the prosperity I had abandoned in Paris under the patronage of that marvellous King

Francis, where I had abundance of all kinds, and here had everything to want for. Many a time I had it in my soul to cast myself away for lost. One day on one of these occasions, I mounted a nice nag I had, put a hundred crowns in my purse, and went to Fiesole to visit a natural son of mine there, who was at nurse with my gossip, the wife of one of my workpeople. When I reached the house, I found the boy in good health, and kissed him, very sad at heart. On taking leave, he would not let me go, but held me with his little hands and a tempest of cries and tears. Considering that he was only two years old or thereabouts, the child's grief was something wonderful. Now I had resolved, in the heat of my despair, if I met Bandinello, who went every evening to a farm of his above San Domenico, that I would hurl him to destruction; so I disengaged myself from my baby, and left the boy there sobbing his heart out. Taking the road toward Florence, just when I entered the piazza of San Domenico, Bandinello was arriving from the other side. On the instant I decided upon bloodshed; but when I reached the man and raised my eyes, I saw him unarmed, riding a sorry mule or rather donkey, and he had with him a boy of ten years old. No sooner did he catch sight of me than he turned the colour of a corpse, and trembled from head to foot. Perceiving at once how base the business would be,

I exclaimed: "Fear not, vile coward! I do not condescend to smite you." He looked at me submissively and said nothing. Thereupon I recovered command of my faculties, and thanked God that His Goodness had withheld me from so great an act of violence. Then, being delivered from that fiendish fury, my spirits rose, and I said to myself: "If God but grant me to execute my work, I hope by its means to annihilate all my scoundrelly enemies; and thus I shall perform far greater and more glorious revenges than if I had vented my rage upon one single foe." Having this excellent resolve in heart, I reached my home. At the end of three days news was brought me that my only son had been smothered by his nurse, my gossip, which gave me greater grief than I have ever had in my whole life. However, I knelt upon the ground, and, not without tears, returned thanks to God, as I was wont, exclaiming, "Lord, Thou gavest me the child, and Thou hast taken him; for all Thy dealings I thank Thee with my whole heart." This great sorrow went nigh to depriving me of reason; yet, according to my habit, I made a virtue of necessity, and adapted myself to circumstances as well as I was able.

Having succeeded so well with the cast of the Medusa, I had great hope of bringing my Perseus through; for I had laid the wax on, and felt

confident that it would come out in bronze, as perfectly as the Medusa. The waxen model produced so fine an effect, that when the Duke saw it and was struck with its beauty—whether somebody had persuaded him it could not be carried out with the same finish in metal, or whether he though so for himself—he came to visit me more frequently than usual, and on one occasion said: "Benvenuto, this figure cannot succeed in bronze; the laws of art do not admit of it." These words of his Excellency stung me so sharply that I answered: "My lord, I know how very little confidence you have in me; and I believe the reason of this is that your most illustrious Excellency lends too ready an ear to my calumniators, or else indeed that you do not understand my art." He hardly let me close the sentence when he broke in: "I profess myself a connoisseur, and understand it very well indeed." I replied: "Yes, like a prince, not like an artist; for if your Excellency understood my trade as well as you imagine, you would trust me on the proofs I have already given. These are, first, the colossal bronze bust of your Excellency, which is now in Elba; * secondly, the restoration of the Ganymede in marble, which offered so many difficulties and cost me so much trouble, that I would rather have made the whole statue new from the beginning; thirdly, the Medusa, cast by me in bronze,

* At Portoferraio. It came afterwards to Florence.

here now before your Excellency's eyes, the execution of which was a greater triumph of strength and skill than any of my predecessors in this fiendish art have yet achieved. Look you, my lord! I constructed that furnace anew on principles quite different from those of other founders; in addition to many technical improvements and ingenious devices, I supplied it with two issues for the metal, because this difficult and twisted figure could not otherwise have come out perfect. It is only owing to my intelligent insight into means and appliances that the statue turned out as it did; a triumph judged impossible by all the practitioners of this art. I should like you furthermore to be aware, my lord, for certain, that the sole reason why I succeeded with all those great and arduous works in France under his most admirable Majesty King Francis, was the high courage which that good monarch put into my heart by the liberal allowances he made me, and the multitude of workpeople he left at my disposal. I could have as many as I asked for, and employed at times above forty, all chosen by myself. These were the cause of my having there produced so many masterpieces in so short a space of time. Now then, my lord, put trust in me; supply me with the aid I need. I am confident of being able to complete a work which will delight your soul. But if your Excellency goes on disheartening me, and does not advance me the assist-

ance which is absolutely required, neither I nor any man alive upon this earth can hope to achieve the slightest thing of value."

It was as much as the Duke could do to stand by and listen to my pleadings. He kept turning first this way and then that; while I, in despair, poor wretched I, was calling up remembrance of the noble state I held in France, to the great sorrow of my soul. All at once he cried: "Come, tell me, Benvenuto, how is it possible that yonder splendid head of Medusa, so high up there in the grasp of Perseus, should ever come out perfect?" I replied upon the instant: "Look you now, my lord! If your Excellency possessed that knowledge of the craft which you affirm you have, you would not fear one moment for the splendid head you speak of. There is good reason, on the other hand, to feel uneasy about this right foot, so far below and at a distance from the rest." When he heard these words, the Duke turned, half in anger, to some gentlemen in waiting, and exclaimed: "I verily believe that this Benvenuto prides himself on contradicting everything one says." Then he faced round to me with a touch of mockery, upon which his attendants did the like, and began to speak as follows: "I will listen patiently to any argument you can possibly produce in explanation of your statement, which may convince me of its probability." I said in answer: "I will ad-

duce so sound an argument that your Excellency shall perceive the full force of it." So I began: "You must know, my lord, that the nature of fire is to ascend, and therefore I promise you that Medusa's head will come out famously; but since it is not in the nature of fire to descend, and I must force it downwards six cubits by artificial means, I assure your Excellency upon this most convincing ground of proof that the foot cannot possibly come out. It will, however, be quite easy for me to restore it." "Why, then," said the Duke, "did you not devise it so that the foot should come out as well as you affirm the head will?" I answered: "I must have made a much larger furnace, with a conduit as thick as my leg; and so I might have forced the molten metal by its own weight to descend so far. Now, my pipe, which runs six cubits to the statue's foot, as I have said is not thicker than two fingers. However, it was not worth the trouble and expense to make a larger; for I shall easily be able to mend what is lacking. But when my mould is more than half full, as I expect, from this middle point upwards, the fire ascending by its natural property, then the heads of Perseus and Medusa will come out admirably; you may be quite sure of it." After I had thus expounded these convincing arguments, together with many more of the same kind, which it would be tedious to set

down here, the Duke shook his head and departed without further ceremony.

Abandoned thus to my own resources, I took new courage and banished the sad thoughts which kept recurring to my mind, making me often weep bitter tears of repentance for having left France; for though I did so only to revisit Florence, my sweet birthplace, in order that I might charitably succour my six nieces, this good action, as I well perceived, had been the beginning of my great misfortune. Nevertheless, I felt convinced that when my Perseus was accomplished, all these trials would be turned to high felicity and glorious well-being.

Accordingly I strengthened my heart, and with all the forces of my body and my purse, employing what little money still remained to me, I set to work. First I provided myself with several loads of pinewood from the forests of Serristori, in the neighbourhood of Montelupo. While these were on their way, I clothed my Perseus with the clay which I had prepared many months beforehand, in order that it might be duly seasoned. After making its clay tunic (for that is the term used in this art) and properly arming it and fencing it with iron girders, I began to draw the wax out by means of a slow fire. This melted and issued through numerous air-vents I had made; for the more there are of these, the better

will the mould fill. When I had finished drawing off the wax, I constructed a funnel-shaped furnace all round the model of my Perseus.* It was built of bricks, so interlaced, the one above the other, that numerous apertures were left for the fire to exhale at. Then I began to lay on wood by degrees, and kept it burning two whole days and nights. At length, when all the wax was gone, and the mould was well baked, I set to work at digging the pit in which to sink it. This I performed with scrupulous regard to all the rules of art. When I had finished that part of my work, I raised the mould by windlasses and stout ropes to a perpendicular position, and suspending it with the greatest care one cubit above the level of the furnace, so that it hung exactly above the middle of the pit, I next lowered it gently down into the very bottom of the furnace, and had it firmly placed with every possible precaution for its safety. When this delicate operation was accomplished, I began to bank it up with the earth I had excavated; and, ever as the earth grew higher, I introduced its proper air-vents, which were little tubes of earthenware, such as folk use for drains and such-like purposes.† At length,

*This furnace, called *manica,* was like a grain-hopper, so that the mould could stand upright in it as in a cup. The word *manica,* is the same as our *manuch,* an antique form of sleeve.

†These air-vents, or *sfiatatoi,* were introduced into the outer mould, which Cellini calls the *tonaca,* or

I felt sure that it was admirably fixed, and that the filling-in of the pit and the placing of the air-vents had been properly performed. I also could see that my workpeople understood my method, which differed very considerably from that of all the other masters in the trade. Feeling confident, then, that I could rely upon them, I next turned to my furnace, which I had filled with numerous pigs of copper and other bronze stuff. The pieces were piled according to the laws of art, that is to say, so resting one upon the other that the flames could play freely through them, in order that the metal might heat and liquefy the sooner. At last I called out heartily to set the furnace going. The logs of pine were heaped in, and, what with the unctuous resin of the wood and the good draught I had given, my furnace worked so well that I was obliged to rush from side to side to keep it going. The labour was more than I could stand; yet I forced myself to strain every nerve and muscle. To increase my anxieties, the workshop took fire, and we were afraid lest the roof should fall upon our heads; while, from the garden, such a storm of wind and

clay tunic laid upon the original model of baked clay and wax. They served the double purpose of drawing off the wax, whereby a space was left for the molten bronze to enter, and also of facilitating the penetration of this molten metal by allowing a free escape of air and gas from the outer mould.

rain kept blowing in, that it perceptibly cooled the furnace.

Battling thus with all these untoward circumstances for several hours, and exerting myself beyond even the measure of my powerful constitution, I could at last bear up no longer, and a sudden fever,* of the utmost possible intensity, attacked me. I felt absolutely obliged to go and fling myself upon my bed. Sorely against my will having to drag myself away from the spot, I turned to my assistants, about ten or more in all, what with master-founders, hand-workers, country-fellows, and my own special journeymen, among whom was Bernardino Mannellini of Mugello, my apprentice through several years. To him in particular I spoke: "Look, my dear Bernardino, that you observe the rules which I have taught you; do your best with all despatch, for the metal will soon be fused. You cannot go wrong; these honest men will get the channels ready; you will easily be able to drive back the two plugs with this pair of iron crooks; and I am sure that my mould will fill miraculously. I feel more ill than I ever did in all my life, and verily believe that it will kill me before a few hours are over." † Thus, with despair at

* *Una febbre efimera.* Lit., *a fever of one day's duration.*

† Some technical terms require explanation in this sentence. The *canali* or channels were sluices for

heart, I left them, and betook myself to bed.

No sooner had I got to bed, than I ordered my serving-maids to carry food and wine for all the men into the workshop; at the same time I cried: "I shall not be alive to-morrow." They tried to encourage me, arguing that my illness would pass over, since it came from excessive fatigue. In this way I spent two hours battling with the fever, which steadily increased, and calling out continually: "I feel that I am dying." My housekeeper, who was named Mona Fiore da Castel del Rio, a very notable manager and no less warm-hearted, kept chiding me for my discouragement; but, on the other hand, she paid me every kind attention which was possible. However, the sight of my physical pain and moral

carrying the molten metal from the furnace into the mould. The *mandriani,* which I have translated by *iron crooks,* were poles fitted at the end with curved irons, by which the openings of the furnace, *plugs,* or in Italian *spine,* could be partially or wholly driven back, so as to let the molten metal flow through the channels into the mould. When the metal reached the mould, it entered in a red-hot stream between the *tonaca,* or outside mould, and the *anima,* or inner block, filling up exactly the space which had previously been occupied by the wax extracted by a method of slow burning alluded to above. I believe that the process is known as casting *á cire perdue.* The *forma,* or mould, consisted of two pieces; one hollow (*la tonaca*), which gave shape to the bronze; one solid and rounded (*la anima*), which stood at a short interval within the former, and regulated the influx of the metal.

dejection so affected her, that, in spite of that brave heart of hers, she could not refrain from shedding tears; and yet, so far as she was able, she took good care I should not see them. While I was thus terribly afflicted, I beheld the figure of a man enter my chamber, twisted in his body into the form of a capital S. He raised a lamentable, doleful voice, like one who announces their last hour to men condemned to die upon the scaffold, and spoke these words: "O Benvenuto! your statue is spoiled, and there is no hope whatever of saving it." No sooner had I heard the shriek of that wretch than I gave a howl which might have been heard from the sphere of flame. Jumping from my bed, I seized my clothes and began to dress. The maids, and my lad, and every one who came around to help me, got kicks or blows of the fist, while I kept crying out in lamentation: "Ah! traitors! enviers! This is an act of treason, done by malice prepense! But I swear by God that I will sift it to the bottom, and before I die will leave such witness to the world of what I can do as shall make a score of mortals marvel."

When I had got my clothes on, I strode with soul bent on mischief toward the workshop; there I beheld the men, whom I had left erewhile in such high spirits, standing stupefied and downcast. I began at once and spoke: "Up with you! Attend to me! Since you have not

been able or willing to obey the directions I gave you, obey me now that I am with you to conduct my work in person. Let no one contradict me, for in cases like this we need the aid of hand and hearing, not of advice." When I had uttered these words, a certain Maestro Alessandro Lastricati broke silence and said: "Look out, Benvenuto, you are going to attempt an enterprise which the laws of art do not sanction, and which cannot succeed." I turned upon him with such fury and so full of mischief, that he and all the rest of them exclaimed with one voice: "On then! Give orders! We will obey your least commands, so long as life is left in us." I believe they spoke thus feelingly because they thought I must fall shortly dead upon the ground. I went immediately to inspect the furnace, and found that the metal was all curdled; an accident which we express by "being caked." * I told two of the hands to cross the road, and fetch from the house of the butcher Capretta a load of young oak-wood, which had lain dry for above a year; this wood had been previously offered me by Madame Ginevra, wife of the said Capretta. So soon as the first armfuls arrived, I began to fill the grate beneath the furnace.† Now oak-wood of that kind heats more powerfully than any sort

* *Essersi fatto un migliaccio.*

† The Italian is *bracciaiuola,* a pit below the grating, which receives the ashes from the furnace.

of tree; and for this reason, where a slow fire is wanted, as in the case of gun-foundry, alder or pine is preferred. Accordingly, when the logs took fire, oh! how the cake began to stir beneath that awful heat, to glow and sparkle in a blaze! At the same time I kept stirring up the channels, and sent men upon the roof to stop the conflagration, which had gathered force from the increased combustion in the furnace; also I caused boards, carpets, and other hangings to be set up against the garden, in order to protect us from the violence of the rain.

When I had thus provided against these several disasters, I roared out first to one man and then to another: "Bring this thing here! Take that thing there!" At this crisis, when the whole gang saw the cake was on the point of melting, they did my bidding, each fellow working with the strength of three. I then ordered half a pig of pewter to be brought, which weighed about sixty pounds, and flung it into the middle of the cake inside the furnace. By this means, and by piling on wood and stirring now with pokers and now with iron rods, the curdled mass rapidly began to liquefy. Then, knowing I had brought the dead to life again, against the firm opinion of those ignoramuses, I felt such vigour fill my veins, that all those pains of fever, all those fears of death, were quite forgotten.

All of a sudden an explosion took place, attended by a tremendous flash of flame, as though a thunderbolt had formed and been discharged amongst us. Unwonted and appalling terror astonished every one, and me more even than the rest. When the din was over and the dazzling light extinguished, we began to look each other in the face. Then I discovered that the cap of the furnace had blown up, and the bronze was bubbling over from its source beneath. So I had the mouths of my mould immediately opened, and at the same time drove in the two plugs which kept back the molten metal. But I noticed that it did not flow as rapidly as usual, the reason being probably that the fierce heat of the fire we kindled had consumed its base alloy. Accordingly I sent for all my pewter platters, porringers, and dishes, to the number of some two hundred pieces, and had a portion of them cast, one by one, into the channels, the rest into the furnace. This expedient succeeded, and every one could now perceive that my bronze was in most perfect liquefaction, and my mould was filling: whereupon they all with heartiness and happy cheer assisted and obeyed my bidding, while I, now here, now there, gave orders, helped with my own hands, and cried aloud: "O God! Thou that by Thy immeasurable power didst rise from the dead, and in Thy glory didst ascend to heaven!" . . . even thus in a moment my mould

was filled; and seeing my work finished, I fell upon my knees, and with all my heart gave thanks to God.

After all was over, I turned to a plate of salad on a bench there, and ate with hearty appetite, and drank together with the whole crew. Afterwards I retired to bed, healthy and happy, for it was now two hours before morning, and slept as sweetly as though I had never felt a touch of illness. My good housekeeper, without my giving any orders, had prepared a fat capon for my repast. So that, when I rose, about the hour for breaking fast, she presented herself with a smiling countenance, and said: "Oh! is that the man who felt that he was dying? Upon my word, I think the blows and kicks you dealt us last night, when you were so enraged, and had that demon in your body as it seemed, must have frightened away your mortal fever! The fever feared that it might catch it, too, as we did!" All my poor household, relieved in like measure from anxiety and overwhelming labour, went at once to buy earthen vessels in order to replace the pewter I had cast away. Then we dined together joyfully; nay, I cannot remember a day in my whole life when I dined with greater gladness or a better appetite.

After our meal I received visits from the several men who had assisted me. They ex-

changed congratulations, and thanked God for our success, saying they had learned and seen things done which other masters judged impossible. I, too, grew somewhat glorious; and deeming I had shown myself a man of talent, indulged a boastful humour. So I thrust my hand into my purse, and paid them all to their full satisfaction.

That evil fellow, my mortal foe, Messer Piero Francesco Ricci, majordomo of the Duke, took great pains to find out how the affair had gone. In answer to his questions, the two men whom I suspected of having caked my metal for me, said I was no man, but of a certainty some powerful devil, since I had accomplished what no craft of the art could do; indeed they did not believe a mere ordinary fiend could work such miracles as I in other ways had shown. They exaggerated the whole affair so much, possibly in order to excuse their own part in it, that the majordomo wrote an account to the Duke, who was then in Pisa, far more marvellous and full of thrilling incidents than what they had narrated.

After I had let my statue cool for two whole days, I began to uncover it by slow degrees. The first thing I found was that the head of Medusa had come out most admirably, thanks to the air-vents; for, as I had told the Duke, it is the na-

ture of fire to ascend. Upon advancing farther, I discovered that the other head, that, namely, of Perseus, had succeeded no less admirably; and this astonished me far more, because it is at a considerably lower level than that of the Medusa. Now the mouths of the mould were placed above the head of Perseus and behind his shoulders; and I found that all the bronze my furnace contained had been exhausted in the head of this figure. It was a miracle to observe that not one fragment remained in the orifice of the channel, and that nothing was wanting to the statue. In my great astonishment I seemed to see in this the hand of God arranging and controlling all.

I went on uncovering the statue with success, and ascertained that everything had come out in perfect order, until I reached the foot of the right leg on which the statue rests. There the heel itself was formed, and going farther, I found the foot apparently complete. This gave me great joy on the one side, but was half unwelcome to me on the other, merely because I had told the Duke that it could not come out. However, when I reached the end, it appeared that the toes and a little piece above them were unfinished, so that about half the foot was wanting. Although I knew that this would add a trifle to my labour, I was very well pleased, because I could now prove to the Duke how well I understood my business. It is true that far more of the foot than

I expected had been perfectly formed; the reason of this was that, from causes I have recently described, the bronze was hotter than our rules of art prescribe; also that I had been obliged to supplement the alloy with my pewter cups and platters, which no one else, I think, had ever done before.

Having now ascertained how successfully my work had been accomplished, I lost no time in hurrying to Pisa, where I found the Duke. He gave me a most gracious reception, as did also the Duchess; and although the majordomo had informed them of the whole proceedings, their Excellencies deemed my performance far more stupendous and astonishing when they heard the tale from my own mouth. When I arrived at the foot of Perseus, and said it had not come out perfect, just as I previously warned his Excellency, I saw an expression of wonder pass over his face, while he related to the Duchess how I had predicted this beforehand.

BENVENUTO CELLINI.

(*Translation by John Addington Symonds*).

THE FIRST OF THE MICROBE HUNTERS*

I

TWO hundred and fifty years ago an obscure man named Leeuwenhoek looked for the first time into a mysterious new world peopled with a thousand different kinds of tiny beings, some ferocious and deadly, others friendly and useful, many of them more important to mankind than any continent or archipelago.

Leeuwenhoek, unsung and scarce remembered, is now almost as unknown as his strange little animals and plants were at the time he discovered them. This is the story of Leeuwenhoek, the first of the microbe hunters. It is the tale of the bold and persistent and curious explorers and fighters of death who came after him. It is the plain history of their tireless peerings into this new fantastic world. They have tried to chart it, these microbe hunters and death fighters. So trying they have groped and fumbled and made mistakes and roused vain hopes. Some of them who were too bold have died—done to death by the

immensely small assassins they were studying—and these have passed to an obscure small glory.

To-day it is respectable to be a man of science. Those who go by the name of scientist form an important element of the population, their laboratories are in every city, their achievements are on the front pages of the newspapers, often before they are fully achieved. Almost any young university student can go in for research and by and by become a comfortable science professor at a tidy little salary in a cozy college. But take yourself back to Leeuwenhoek's day, two hundred and fifty years ago, and imagine yourself just through high school, getting ready to choose a career, wanting to know—

You have lately recovered from an attack of mumps, you ask your father what is the cause of mumps and he tells you a mumpish evil spirit has got into you. His theory may not impress you much, but you decide to make believe you believe him and not to wonder any more about what is mumps—because if you publicly don't believe him you are in for a beating and may even be turned out of the house. Your father is Authority.

That was the world three hundred years ago, when Leeuwenhoek was born. It had hardly begun to shake itself free from superstitions, it was barely beginning to blush for its ignorance. It was a world where science (which only means

trying to find truth by careful observation and clear thinking) was just learning to toddle on vague and wobbly legs. It was a world where Servetus was burned to death for daring to cut up and examine the body of a dead man, where Galileo was shut up for life for daring to prove that the earth moved around the sun.

Antony Leeuwenhoek was born in 1632 amid the blue windmills and low streets and high canals of Delft, in Holland. His family were burghers of an intensely respectable kind and I say intensely respectable because they were basket-makers and brewers, and brewers are respectable and highly honoured in Holland. Leeuwenhoek's father died early and his mother sent him to school to learn to be a government official, but he left school at sixteen to be an apprentice in a dry-goods store in Amsterdam. That was his university. Think of a present-day scientist getting his training for experiment among bolts of gingham, listening to the tinkle of the bell on the cash drawer, being polite to an eternal succession of Dutch housewives who shopped with a penny-pinching dreadful exhaustiveness—but that was Leeuwenhoek's university, for six years!

At the age of twenty-one he left the dry-goods store, went back to Delft, married, set up a dry-goods store of his own there. For twenty years after that very little is known about him, except that he had two wives (in succession) and several

children most of whom died, but there is no doubt that during this time he was appointed janitor of the city hall of Delft, and that he developed a most idiotic love for grinding lenses. He had heard that if you very carefully ground very little lenses out of clear glass, you would see things look much bigger than they appeared to the naked eye. . . . Little is known about him from twenty to forty, but there is no doubt that he passed in those days for an ignorant man. The only language he knew was Dutch—that was an obscure language despised by the cultured world as a tongue of fishermen and shop-keepers and diggers of ditches. Educated men talked Latin in those days, but Leeuwenhoek could not so much as read it and his only literature was the Dutch Bible. Just the same, you will see that his ignorance was a great help to him, for, cut off from all of the learned nonsense of his time, he had to trust to his own eyes, his own thoughts, his own judgment. And that was easy for him because there never was a more mulish man than this Antony Leeuwenhoek!

It would be great fun to look through a lens and see things bigger than your naked eye showed them to you! But *buy* lenses? Not Leeuwenhoek! There never was a more suspicious man. Buy lenses? He would make them himself! During these twenty years of his obscurity he went to spectacle-makers and got the rudiments of lens-

grinding. He visited alchemists and apothecaries and put his nose into their secret ways of getting metals from ores, he began fumblingly to learn the craft of the gold- and silversmiths. He was a most pernickety man and was not satisfied with grinding lenses as good as those of the best lens-grinder in Holland, they had to be better than the best, and then he still fussed over them for long hours. Next he mounted these lenses in little oblongs of copper or silver or gold, which he had extracted himself, over hot fires, among strange smells and fumes. To-day searchers pay seventy-five dollars for a fine shining microscope, turn the screws, peer through it, make discoveries—without knowing anything about how it is built. But Leeuwenhoek—

Of course his neighbours thought he was a bit cracked but Leeuwenhoek went on burning and blistering his hands. Working forgetful of his family and regardless of his friends, he bent solitary to subtle tasks in still nights. The good neighbours sniggered, while that man found a way to make a tiny lens, less than one-eighth of an inch across, so symmetrical, so perfect, that it showed little things to him with a fantastic clear enormousness. Yes, he was a very uncultured man, but he alone of all men in Holland knew how to make those lenses, and he said of those neighbours: "We must forgive them, seeing that they know no better."

Now this self-satisfied dry-goods dealer began to turn his lenses onto everything he could get hold of. He looked through them at the muscle fibres of a whale and the scales of his own skin. He went to the butcher shop and begged or bought ox-eyes and was amazed at how prettily the crystalline lens of the eye of the ox is put together. He peered for hours at the build of the hairs of a sheep, of a beaver, of an elk, that were transformed from their fineness into great rough logs under his bit of glass. He delicately dissected the head of a fly; he stuck its brain on the fine needle of his microscope—how he admired the clear details of the marvellous big brain of that fly! He examined the cross-sections of the wood of a dozen different trees and squinted at the seeds of plants. He grunted "Impossible!" when he first spied the outlandish large perfection of the sting of a flea and the legs of a louse. That man Leeuwenhoek was like a puppy who sniffs—with a totally impolite disregard of discrimination—at every object of the world around him!

II

There never was a less sure man than Leeuwenhoek. He looked at this bee's sting or that louse's leg again and again and again. He left his specimens sticking on the point of his strange

microscope for months—in order to look at other things he made more microscopes till he had hundreds of them!—then he came back to those first specimens to correct his first mistakes. He never set down a word about anything he peeped at, he never made a drawing until hundreds of peeps showed him that, under given conditions, he would always see exactly the same thing. And then he was not sure! He said:

"People who look for the first time through a microscope say now I see this and then I see that—and even a skilled observer can be fooled. On these observations I have spent more time than many will believe, but I have done them with joy, and I have taken no notice of those who have said why take so much trouble and what good is it?—but I do not write for such people but only for the philosophical!" He worked for twenty years that way, without an audience.

But at this time, in the middle of the seventeenth century, great things were astir in the world. Here and there in France and England and Italy rare men were thumbing their noses at almost everything that passed for knowledge. "We will no longer take Aristotle's say-so, nor the Pope's say-so," said these rebels. "We will trust only the perpetually repeated observations of our own eyes and the careful weighings of our scales; we will listen to the answers experiments give us and no other answers!" So in England

a few of these revolutionists started a society called The Invisible College, it had to be invisible because that man Cromwell might have hung them for plotters and heretics if he had heard of the strange questions they were trying to settle. What experiments those solemn searchers made! Put a spider in a circle made of the powder of a unicorn's horn and that spider can't crawl out—so said the wisdom of that day. But these Invisible Collegians? One of them brought what was supposed to be powdered unicorn's horn and another came carrying a little spider in a bottle. The college crowded around under the light of high candles. Silence, then the hushed experiment, and here is their report of it:

"A circle was made with the powder of unicorn's horn and a spider set in the middle of it, but it immediately ran out."

Crude, you exclaim. Of course! But remember that one of the members of this college was Robert Boyle, founder of the science of chemistry, and another was Isaac Newton. Such was the Invisible College, and presently, when Charles II came to the throne, it rose from its depths as a sort of blind-pig scientific society to the dignity of the name of the Royal Society of England. And they were Antony Leeuwenhoek's first audience! There was one man in Delft who did not laugh at Antony Leeuwenhoek, and that

was Regnier de Graaf, whom the Lords and Gentlemen of the Royal Society had made a corresponding member because he had written them of interesting things he had found in the human ovary. Already Leeuwenhoek was rather surly and suspected everybody, but he let de Graaf peep through those magic eyes of his, those little lenses whose equal did not exist in Europe or England or the whole world for that matter. What de Graaf saw through those microscopes made him ashamed of his own fame and he hurried to write to the Royal Society:

"Get Antony Leeuwenhoek to write you telling of his discoveries."

And Leeuwenhoek answered the request of the Royal Society with all the confidence of an ignorant man who fails to realize the profound wisdom of the philosophers he addresses. It was a long letter, it rambled over every subject under the sun, it was written with a comical artlessness in the conversational Dutch that was the only language he knew. The title of the letter was: "A Specimen of some Observations made by a Microscope contrived by Mr. Leeuwenhoek, concerning Mould upon the Skin, Flesh, etc.; the Sting of a Bee, etc." The Royal Society was amazed, the sophisticated and learned gentlemen were amused—but principally the Royal Society was astounded by the marvelous things Leeuwen-

hoek told them he could see through his new lenses. The Secretary of the Royal Society thanked Leeuwenhoek and told him he hoped his first communication would be followed by others. It was, by hundreds of others over a period of fifty years. They were talkative letters full of salty remarks about his ignorant neighbours, of exposures of charlatans and of skilled explodings of superstitions, of chatter about his personal health—but sandwiched between paragraphs and pages of this homely stuff, in almost every letter, those Lords and Gentlemen of the Royal Society had the honour of reading immortal and gloriously accurate descriptions of the discoveries made by the magic eye of that janitor and shopkeeper. What discoveries!

When you look back at them, many of the fundamental discoveries of science seem so simple, too absurdly simple. How was it men groped and fumbled for so many thousands of years without seeing things that lay right under their noses? So with microbes. Now all the world has seen them cavorting on movie screens, many people of little learning have peeped at them swimming about under lenses of microscopes, the greenest medical student is able to show you the germs of I don't know how many diseases—what was so hard about seeing microbes for the first time?

But let us drop our sneers to remember that

when Leeuwenhoek was born there were no microscopes but only crude hand-lenses that would hardly make a ten-cent piece look as large as a quarter. Through these—without his incessant grinding of his own marvellous lenses—that Dutchman might have looked till he grew old without discovering any creature smaller than a cheese-mite. You have read that he made better and better lenses with the fanatical persistence of a lunatic; that he examined everything, the most intimate things and the most shocking things, with the silly curiosity of a puppy. Yes, and all this squinting at bee-stings and mustache hairs and whatnot were needful to prepare him for that sudden day when he looked through his toy of a gold-mounted lens at a fraction of a small drop of clear rain water to discover—

What he saw that day starts this history. Leeuwenhoek was a maniac observer, and who but such a strange man would have thought to turn his lens on clear, pure water, just come down from the sky? What could there be in water but just—water? You can imagine his daughter Maria—she was nineteen and she took such care of her slightly insane father!—watching him take a little tube of glass, heat it red-hot in a flame, draw it out to the thinness of a hair. . . . Maria was devoted to her father—let any of those stupid neighbours dare to snigger at him!—

but what in the world was he up to now, with that hair-fine glass pipe?

You can see her watch that absent-minded wide-eyed man break the tube into little pieces, go out into the garden to bend over an earthen pot kept there to measure the fall of the rain. He bends over that pot. He goes back into his study. He sticks the little glass pipe onto the needle of his microscope. . . .

What can that dear silly father be up to?

He squints through his lens. He mutters guttural words under his breath. . . .

Then suddenly the excited voice of Leeuwenhoek: "Come here! Hurry! There are little animals in this rain water. . . . They swim! They play around! They are a thousand times smaller than any creatures we can see with our eyes alone. . . . Look! See what I have discovered!"

Leeuwenhoek's day of days had come. Alexander had gone to India and discovered huge elephants that no Greek had ever seen before—but those elephants were as commonplace to Hindus as horses were to Alexander. Cæsar had gone to England and come upon savages that opened his eyes with wonder—but these Britons were as ordinary to each other as Roman centurions were to Cæsar. Balboa? What were his proud feelings as he looked for the first time at the Pacific? Just the same that Ocean was as

ordinary to a Central American Indian as the Mediterranean was to Balboa. But Leeuwenhoek? This janitor of Delft had stolen upon and peeped into a fantastic sub-visible world of little things, creatures that had lived, had bred, had battled, had died, completely hidden from and unknown to all men from the beginning of time. Beasts these were of a kind that ravaged and annihilated whole races of men ten million times larger than they were themselves. Beings these were, more terrible than fire-spitting dragons or hydra-headed monsters. They were silent assassins that murdered babes in warm cradles and kings in sheltered places. It was this invisible, insignificant, but implacable—and sometimes friendly—world that Leeuwenhoek had looked into for the first time of all men of all countries.

This was Leeuwenhoek's days of days. . . .

PAUL DE KRUIF.

HOATZINS AT HOME*

THE flight of the hoatzin resembles that of an over-fed hen. The hoatzin's voice is no more melodious than the cry of a peacock, and less sonorous than an alligator's roar. The bird's grace is batrachian rather than avian, while the odour of its body resembles that of no bird untouched by dissolution. Still, zoologically considered, the hoatzin is probably the most remarkable and interesting bird living on the earth to-day.

It has successfully defied time and space. For it, the dial of the ages has moved more slowly than for the rest of organic life, and although living and breathing with us to-day, yet its world is an affair of two dimensions—a line of thorny saplings threaded along the muddy banks of a few tropical waters.

A bird in a cage cannot escape, and may be found month after month wherever the cage is placed. A stuffed bird in a case may resist disintegration for a century. But when we go to look for the bluebirds which nest in the orchard,

*From William Beebe's "Jungle Peace" by permission from Henry Holt & Co. publishers.

they may have flown a half mile away in their search for food. The plover which scurries before us to-day on the beach may to-night be far away on the first lap of his seven thousand mile flight to the southward.

The hoatzin's status lies rather with the caged bird. In November in New York City an Englishman from British Guiana said to me, "Go to the Berbice River, and at the north end of the town of New Amsterdam, in front of Mr. Beckett's house, you will find hoatzins." Six months later as I drove along a tropical river road I saw three hoatzins perched on a low thorn bush at the river's edge in front of a house. And the river was the Berbice, and the house that of Mr. Beckett.

Thus are the hoatzins independent of space, as all other flying birds know it, and in their classic reptilian affinities,—voice, actions, arms, fingers, habits,—they bring close the dim epochs of past time, and renew for our inspection the youth of bird-life on the earth. It is discouraging ever to attempt to translate habits fraught with so profound a significance into words, or to make them realistic even with the aid of photographs.

We took a boat opposite Mr. Beckett's house, and paddled slowly with the nearly-flood tide up the Berbice River. It was two o'clock, the hottest time of the day. For three miles we drifted past the chosen haunts of the hoatzins. All were

perched in the shade, quiet in the intense heat, squatting prostrate or sleepily preening their plumage. Now and then we saw a bird on her nest, always over the water. If she was sitting on eggs she sat close. If young birds were in the nest she half-crouched, or perched on the rim, so that her body cast a shadow over the young.

The vegetation was not varied. Muckamucka was here and there in the foreground, with an almost solid line of bunduri pimpler or thorn tree. This was the real home of the birds, and this plant forms the background whenever the hoatzin comes to mind. It is a growth which loves the water, and crowds down so that the rising of the tide, whether fresh or brackish, covers the mud in which it stands, so that it appears to be quite as aquatic as the mangrove which, here and there, creeps out alongside it.

The pimpler bears thorns of the first magnitude, often double, recurved and at such diabolically unexpected places, that like barbed wire, it is impossible to grasp anywhere without drawing blood. Such a chevaux-de-frise would defend a trench against the most courageous regiment. The stems were light grey, greening toward the younger shoots, and the foliage was pleasantly divided into double lines of locust-like leaflets.

The plants were in full flower,—dainty, upright panicles of wisteria-like pea-blooms, pale violet and white with tiny buds of magenta. A

faint, subdued perfume drifted from them through the tangle of branches. The fruit was ripening on many plants, in clusters of green, semi-circular, flat, kidney pods. The low branches stretched gracefully waterwards in long sweeping curves. On these at a fork or at the crossing of two distinct branches, the hoatzins placed their nests, and with the soft-tissued leaflets they packed their capacious crops and fed their young.

Besides these two plants, which alone may be considered as forming the principal environment, two blooms were conspicuous at this season; a deep-calyxed, round blossom of rich yellow,—an hibiscus, which the Indians called makoe, and from the bark of which they made most excellent rope. The other flower was a vine which crept commonly up over the pimpler trees, regardless of water and thorns, and hung out twin blossoms in profusion, pink and pinkish-white, trumpet-shaped, with flaring lips.

The mid-day life about this haunt of hoatzins was full of interest. Tody-flycatchers of two species, yellow-breasted and streaked, were the commonest birds, and their little homes, like bits of tide-hung drift, swayed from the tips of the pimpler branches. They dashed to and fro regardless of the heat, and whenever we stopped they came within a foot or two, curiously watching our every motion. Kiskadees hopped along the water's edge in the shade, snatching insects

and occasionally splashing into the water after small fish. Awkward Guinea green herons, not long out of the nest, crept like shadow silhouettes of birds close to the dark water. High overhead, like flecks of jet against the blue sky, the vultures soared. Green dragonflies whirled here and there, and great blue-black bees fumbled in and out of the hibiscus, yellowed with pollen and too busy to stop a second in their day-long labour.

This little area held very strange creatures as well, some of which we saw even in our few hours' search. Four-eyed fish skittered over the water, pale as the ghosts of fish, and when quiet, showing only as a pair of bubbly eyes. Still more weird hairy caterpillars wriggled their way through the muddy, brackish current—aquatic larvæ of a small moth which I had not seen since I found them in the trenches of Pará.

The only sound at this time of day was a drowsy but penetrating *tr-r-r-r-r-p!* made by a green-bodied, green-legged grasshopper of good size, whose joy in life seemed to be to lie lengthwise upon a pimpler branch and skreek violently at frequent intervals, giving his wings a frantic flutter at each utterance, and slowly encircling the stem.

In such environment the hoatzin lives and thrives, and, thanks to its strong body odour, has existed from time immemorial in the face of terrific handicaps. The odour is a strong musky

one, not particularly disagreeable. I searched my memory at every whiff for something of which it vividly reminded me, and at last the recollection came to me—the smell, delectable and fearfully exciting in former years—of elephants at a circus, and not altogether elephants either, but a compound of one-sixth sawdust, another part peanuts, another of strange animals and three-sixths swaying elephant. That, to my mind, exactly describes the odour of hoatzins as I sensed it among these alien surroundings.

As I have mentioned, the nest of the hoatzin was invariably built over the water, and we shall later discover the reason for this. The nests were sometimes only four feet above high water, or equally rarely, at a height of forty to fifty feet. From six to fifteen feet included the zone of four-fifths of the nests of these birds. They varied much in solidity, some being frail and loosely put together, the dry, dead sticks which composed them dropping apart almost at a touch. Usually they were as well knitted as a heron's, and in about half the cases consisted of a recent nest built upon the foundations of an old one. There was hardly any cavity at the top, and the coarse network of sticks looked like a precarious resting place for eggs and an exceedingly uncomfortable one for young birds.

When we approached a nest, the occupant paid

no attention until we actually came close to a branch, or shook it. She then rose, protesting hoarsely, and lifting wings and tail as she croaked. At the last moment, often when only a yard away, she flew off and away to a distance of fifty feet or more. Watching closely, when she realized that we really had intentions on her nest, she returned and perched fifteen or twenty feet away, croaking continually, her mate a little farther off, and all the hoatzins within sight or hearing joining in sympathetic disharmony, all with synchronous lifting of tail and wings at each utterance.

The voice of the female is appreciably deeper than that of the male, having more of a gurgling character, like one of the notes of a curassow. The usual note of both sexes is an unwritable, hoarse, creaking sound, quite cicada or frog-like.

Their tameness was astounding, and they would often sit unmoved, while we were walking noisily about, or focusing the camera within two yards. If several were sitting on a branch and one was shot, the others would often show no symptoms of concern or alarm, either at the noise of the gun or the fall of their companion. A hoatzin which may have been crouched close to the slain bird would continue to preen its plumage without a glance downward. When the young had attained their first full plumage it

was almost impossible to distinguish them from the older members of the flock except by their generally smaller size.

But the heart of our interest in the hoatzins centred in the nestlings. Some kind of Providence directed the time of our visit, which I chose against the advice of some of the very inhabitants of New Amsterdam. It turned out that we were on the scene exactly at the right time. A week either way would have yielded much poorer results. The nestlings, in seven occupied nests, observed as we drifted along shore, or landed and climbed among the thorns, were in an almost identical stage of development. In fact, the greatest difference in size occurred between two nestlings of the same brood. Their down was a thin, scanty, fuzzy covering, and the flight feathers were less than a half-inch in length. No age would have showed to better advantage every movement of wings or head.

When a mother hoatzin took reluctant flight from her nest, the young bird at once stood upright and looked curiously in every direction. No slacker he, crouching flat or awaiting his mother's directing cries. From the moment he was left alone he began to depend upon the warnings and signs which his great beady eyes and skinny ears conveyed to him. Hawks and vultures had swept low over his nest and mother

unheeded. Coolies in their boats had paddled underneath with no more than a glance upward. Throughout his week of life, as through his parents' and their parents' parents' lives, no danger had disturbed their peaceful existence. Only for a sudden windstorm such as that which the week before had upset nests and blown out eggs, it might be said that for the little hoatzin chicks life held nothing but siestas and munchings of pimpler leaves.

But one little hoatzin, if he had any thoughts such as these, failed to count on the invariable exceptions to every rule, for this day the totally unexpected happened. Fate, in the shape of enthusiastic scientists, descended upon him. He was not for a second nonplussed. If we had concentrated upon him a thousand strong, by boats and by land, he would have fought the good fight for freedom and life as calmly as he waged it against us. And we found him no mean antagonist, and far from reptilian in his ability to meet new and unforeseen conditions.

His mother, who a moment before had been packing his capacious little crop with predigested pimpler leaves, had now flown off to an adjoining group of mangroves, where she and his father croaked to him hoarse encouragement. His flight feathers hardly reached beyond his finger-tips, and his body was covered with a sparse

coating of sooty black down. So there could be no resort to flight. He must defend himself, bound to earth like his assailants.

Hardly had his mother left when his comical head, with thick, blunt beak and large intelligent eyes, appeared over the rim of the nest. His alert expression was increased by the suspicion of a crest on his crown where the down was slightly longer. Higher and higher rose his head, supported on a neck of extraordinary length and thinness. No more than this was needed to mark his absurd resemblance to some strange, extinct reptile. A young dinosaur must have looked much like this, while for all that my glance revealed, I might have been looking at a diminutive Galapagos tortoise. Indeed this simile came to mind often when I became more intimate with nestling hoatzins.

Sam, my black tree-climber, kicked off his shoes and began creeping along the horizontal limbs of the pimplers. At every step he felt carefully with a calloused sole in order to avoid the longer of the cruel thorns, and punctuated every yard with some gasp of pain or muttered personal prayer, "Pleas' doan' stick me, Thorns!"

At last his hand touched the branch, and it shook slightly. The young bird stretched his mittened hands high above his head and waved them a moment. With similar intent a boxer or wrestler flexes his muscles and bends his body.

One or two uncertain, forward steps brought the bird to the edge of the nest at the base of a small branch. There he stood, and raising one wing leaned heavily against the stem, bracing himself. My man climbed higher and the nest swayed violently.

Now the brave little hoatzin reached up to some tiny side twigs and aided by the projecting ends of dead sticks from the nest, he climbed with facility, his thumbs and forefingers apparently being of more aid than his feet. It was fascinating to see him ascend, stopping now and then to crane his head and neck far out, turtle-wise. He met every difficulty with some new contortion of body or limbs, often with so quick or so subtle a shifting as to escape my scrutiny. The branch ended in a tiny crotch and here perforce, ended his attempt at escape by climbing. He stood on the swaying twig, one wing clutched tight, and braced himself with both feet.

Nearer and nearer crept Sam. Not a quiver on the part of the little hoatzin. We did not know it, but inside that ridiculous head there was definite decision as to a deadline. He watched the approach of this great, strange creature—this Danger, this thing so wholly new and foreign to his experience, and doubtless to all the generations of his forbears. A black hand grasped the thorny branch six feet from his perch, and like a flash he played his next trick—the only re-

maining one he knew, one that set him apart from all modern land birds, as the frog is set apart from the swallow.

The young hoatzin stood erect for an instant, and then both wings of the little bird were stretched straight back, not folded, bird-wise, but dangling loosely and reaching well beyond the body. For a considerable fraction of time he leaned forward. Then without effort, without apparent leap or jump he dived straight downward, as beautifully as a seal, direct as a plummet and very swiftly. There was a scarcely-noticeable splash, and as I gazed with real awe, I watched the widening ripples which undulated over the muddy water—the only trace of the whereabouts of the young bird.

It seemed as if no one, whether ornithologist, evolutionist, poet or philosopher could fail to be profoundly impressed at the sight we had seen. Here I was in a very real, a very modern boat, with the honk of motor horns sounding from the river road a few yards away through the bushes, in the shade of this tropical vegetation in the year nineteen hundred and sixteen; and yet the curtain of the past had been lifted and I had been permitted a glimpse of what must have been common in the millions of years ago. It was a tremendous thing, a wonderful thing to have seen, and it seemed to dwarf all the strange sights which had come to me in all other parts

of the earth's wilderness. I had read of these habits and had expected them, but like one's first sight of a volcano in eruption, no reading or description prepares one for the actual phenomenon.

I sat silently watching for the re-appearance of the young bird. We tallied five pairs of eyes and yet many minutes passed before I saw the same little head and emaciated neck sticking out of the water alongside a bit of drift rubbish. The only visible thing was the protruding spikes of the bedraggled tail feathers. I worked the boat in toward the bird, half-heartedly, for I had made up my mind that this particular brave little bit of atavism deserved his freedom, so splendidly had he fought for it among the pimplers. Soon he ducked forward, dived out of sight and came up twenty feet away among an inextricable tangle of vines. I sent a little cheer of well wishing after him and we salvaged Sam.

Then we shoved out the boat and watched from a distance. Five or six minutes passed and a skinny, crooked, two-fingered mitten of an arm reared upward out of the muddy flood and the nestling, black and glistening, hauled itself out of water.

Thus must the first amphibian have climbed into the thin air. But the young hoatzin neither gasped nor shivered, and seemed as self-possessed as if this was a common occurrence in its life.

There was not the slightest doubt however, that this was its first introduction to water. Yet it had dived from a height of fifteen feet, about fifty times its own length, as cleanly as a seal leaps from a berg. It was as if a human child should dive *two hundred feet!*

In fifteen minutes more it had climbed high above the water, and with unerring accuracy directly toward its natal bundle of sticks overhead. The mother now came close, and with hoarse rasping notes and frantic heaves of tail and wings lent encouragement. Just before we paddled from sight, when the little fellow had reached his last rung, he partly opened his beak and gave a little falsetto cry,—a clear, high tone, tailing off into a guttural rasp. His splendid courage had broken at last; he had nearly reached the nest and he was aching to put aside all this terrible responsibility, this pitting of his tiny might against such fearful odds. He wanted to be a helpless nestling again, to crouch on the springy bed of twigs with a feather comforter over him and be stuffed at will with delectable pimpler pap. Such is the normal right destiny of a hoatzin chick, and the *whee-og!* wrung from him by the reaction of safety seemed to voice all this.

WILLIAM BEEBE.

BATS*

THE bat was formerly looked upon as an uncanny sort of bird, and described as such in the old natural histories. Oh, those ever delightful old natural histories, and the vision of the wise old naturalist examining a recently-taken specimen through his horn-bound spectacles, and setting it gravely down in his books that it is the only known bird which was clothed in fur in place of feathers! Or, as Plinius puts it, the only bird which brings forth and suckles its young, just as we say that the Australian water-mole is the only mammal which lays eggs. The modern ornithologist will have nothing to do with the creature; but after his expulsion from the feathered nation it was his singular good fortune not to sink lower in the scale; he was, on the contrary, raised to the mammalians, or quadrupeds, as our fathers called them; then on the discovery being made that he was anatomically related to the lemurs, he was eventually allotted a place in our systems next after that ancient order of fox-faced monkeys. And thus it has

*From "The Book of a Naturalist" by permission of the publishers, E. P. Dutton & Co.

come to pass that when some one writes a book on the mammals of this island, which has no monkeys or lemurs, and man cannot be included in such works on account of an old convention or prejudice, he is obliged to give the proud first place to this very poor relation.

It is his misfortune, since it would have been more agreeable to the general reader if he could have led off with some imposing beast—the extinct wolf or tusky wild boar, for example—or, better still, with the white cattle of Chillingham, or the roaring stag with his grand antlers. The last is an undoubted survival, one which, encountered in some incult place where it is absolutely free and wild, moves us to a strange joy —an inherited memory and a vision of a savage, prehistoric land of which we are truer natives than we can ever be of this smooth sophisticated England. The science of zoology could not have it so, since it does not and cannot take man and his mental attitude towards other forms of life into account—cannot consider the fact that he is himself an animal of prey, several feet high, with large eyes fitted to look at large objects, and that he measures and classifies all creatures by an instinctive rule and standard, mentally pitting his strength and ferocity against theirs. What a discrepancy, then, between things as seen by the natural man and as they appear in our scientific systems, which make the small

negligible bat the leader of the procession of British beasts—even this repulsive little rear-mouse, or flittermouse, that flits from his evil-smelling cranny, in appearance a misshapen insect of unusual size to pursue his crooked, bróken-boned, squeaky flight in the obscurity of evening.

Imagine the effect of this modern rearrangement of the mammals on the mammals if they knew! The white bull of Chillingham would shake his frowning front and the stag his branching antlers in scorn; the wolf, in spite of being extinct, would howl; the British seal bark; the wild cat snarl, and the badger make free use of his most underground expressions of rage at such an insult; rabbit and hare would exchange looks of astonishment and apprehension; the hedgehog would roll himself into a ball with disgust; the mole sink back into his run; the fox smile sardonically; and the whole concourse, turning their backs on the contemptible leader thrust on them, would march off in the opposite direction.

Now the imaginary case of these beasts offended in their dignity fairly represents that of humanity angry at the intolerable insult implied in the Darwinian notion. But we have now so far outgrown that feeling that it is no longer an offence for the zoologist to tell us not only that we are related to the lemur with its luminous

opalescent or topaz eyes, that are like the eyes of angels and are instinct with a mysterious intelligence when they look at us with a strange friendliness in them as if they knew what we, after thousands of years of thinking, have only just found out—not only that this animal is our relation, but even such a creature as the bat!

Look on this picture, and on this! On the eyes, for instance, of these two beasts, and we see at once that the bat is an example of extreme degeneration; also that it is the most striking example in the animal world of a degenerate in which the downward process has at length been arrested, and instead of extinction a new, different, and probably infinitely longer life given to it.

We are reminded of the flea—the remote descendant, as we deem, of a gilded fly that was once free of the air and feasted at the same sunlit flowery table with bright-winged butterflies and noble wasps and bees.

There are those who have doubts about this genealogical tree of the bat, and would have it that he is an insectivore related to moles, shrews, and such-like low-down animals, but the main facts all point the other way. And we may assume that the bat—our familiar flittermouse, since we are not concerned with the somewhat different frugivorous bats of the tropics—is the remote descendant of a small degenerate lemur

that inhabited the upper branches of high trees in the African forest; that he became exclusively insectivorous and developed an extreme activity in capturing his winged prey, and was in fact like the existing small lemur, the golago, which in pursuing insects "seems literally to fly through the air," as Sir H. Johnston has said. Finally, there was the further development, the ovidean metamorphosis, when the loose expanding membrane of the hands and arms and sides grew to wings.

But albeit like a bird in its faculty of flight, the bat was a mammal still, and was rather like a badly constructed flying-machine, at best an improvement on the parachute. This then was a risky experiment on Nature's part, seeing that to launch a mammal on the air is to put it into competition with birds, and throw it in the way of its rapacious bird enemies, natives of that element and infinitely its superior in flying powers. But Nature, we see, takes risks of this kind with a very light heart; her busy brain teems with thousands, millions, of inventions, and if nine hundred and ninety-nine in a thousand go wrong, she simply scraps them and goes cheerfully on with her everlasting business. An amusing person! One can imagine some Principality or High Intelligence, a visitor from Aldebaran, let us say, looking on at these queer doings on her part and remarking: "My dear, what a silly

fool you are to waste so much energy in trying to do an impossible thing."

And—nettled at his air of superiority—her sharp reply:

"Oh yes, now you say that, I'm reminded of a visitor I once had from—oh, I don't know exactly where—somewhere in the Milky Way—just when I was experimenting with my snake idea. To make a vertebrate without any organs of progression, yet capable of getting freely about—ha, ha, ha, how very funny! I'd like him to come back now to show him a tree-snake with a cylindrical body two yards long and no thicker than a man's middle finger, green as a green leaf and smooth as ivory, going as freely about in a tree as a cat or a monkey. Also my blue sea-snake, cleaving the water like a fish; also my ground-serpents of numberless types, moving swiftly over the earth with a grace surpassing that of creatures endowed with organs of progression."

But not a word did she say about the flying-fish, which was not a great success.

Then he: "Well, I should advise the person from the Milky Way to keep out of *your* way. No doubt you have done clever things, but the snake problem was not so very difficult after all. You thought of the rib and the scale, and the thing was done."

And she: "Yes, it was quite simple, and so

when I wanted to make reptiles fly I thought of this and of that and of something else and the thing was done."

Then he: "Yes, yes, my dear lady—that was clever, too, no doubt; only your flying lizard wasn't wound up to go on for ever—not as a lizard at all events; and what I should like you to tell me is: When you have got your little beast in the air how are you going to get him to stay there?"

Her sharp reply was: "By thinking," for she was angry at his supercilious Aldebaran airs. And, put on her mettle, it was only by sheer hard thinking that she finally succeeded in accomplishing her object—this, too, as it were, by means of a subtle trick. For the bird problem had been a very different one; her experiments with flying lizards had suggested it, and she was able to create this new and finer being an inhabitant of the air by giving it its peculiar pointed wedge shape, its covering of feathers, with feathers for flight—hard as steel, light as gossamer, bloodless, nerveless. And correlated with shape and flight and life in the air, a development of power of vision which, compared with that of mammals and reptiles, is like a supernatural faculty.

Her subtle trick, in the case of the bat, was to reverse the process followed in building up the bird; to suspend her beast head down by the toes instead of making him perch with his head

up to keep it cool; to neglect the vision altogether as of little or no account; and, on the other hand, instead of the light, hard, nerveless feather wings, to make the flying apparatus the most sensitive thing in Nature, barring the antennae of insects; a bed and field of nerves, so closely placed as to give the membrane the appearance of the finest, softest shot silk. The brains of the creature, as it were, are carried spread out on its wings, and so exquisitely delicate is the sensitiveness of these parts that in comparison our finger-tips are no more quick of feeling than the thick tough hide of some lumbering pachyderm.

I have handled scores of bats in my time, and have never had one in my hand without being struck by its shrinking, shivering motions, the tremors that passed over it like wave following wave, and it has seemed to me that the touch of a soft finger-tip on its wing was to the bat like a blow of a cheese- or bread-grater on his naked body to a man.

Now any one, even the intelligent foreigner from Aldebaran, would have imagined that such a creature so constructed would not have maintained its existence in this rough world: a sudden storm of rain or hail encountered in mid-air would have destroyed it, and in its pursuit of insects in leafy places it would have been exposed every minute to disabling accidents. But

it did not happen so. That exquisite super-sensitiveness, that extra sense, or extra senses, since we do not know how many there are, not only kept it in the air, able to continue the struggle of life in the particular forest, the district, the region, the continent where it came into being, but sent it abroad, an invader and colonist, to other lands, other continents all over the globe, including those far-off isolated islands which had been cut off from all connexion with the rest of the earth before mammalian life was evolved, and had no higher life than birds, until this small beast came flying over the illimitable ocean on his wings, to be followed a million years later by his noble relation in a canoe.

We see then that the bat is a very wonderful creature, one of Nature's triumphs and masterpieces, and on this account he has received a good share of attention from zoologists. Nevertheless, after looking through a large amount of literature on the subject, the old idea persists that we know little about the bat—little, that is to say, compared with all there is to be known. How very little my own researches can add to its life history these meagre observations and comments will serve to show.

Walking by the Test, near Longparish, one evening, I noticed a number of noctules, our great bat, gathered at a spot where some high trees, elms and beeches, grew on the edge of a

wet meadow. The bats were flying up and down in front of the trees, feasting on the moths and other insects that abounded there. I wondered how it came about that these big bats had this rich table all to themselves, seeing that the small common bat is by far the most numerous species in that locality. After I had stood there watching them for a few minutes a common bat appeared, and at once began flying to and fro among them; but very soon he was spotted and attacked by a big bat, and then began the maddest chase it was possible to see, the little one doubling wildly this way and that, now mounting high in the air, then plunging downward to the grass, anon losing himself in the trees, to reappear in a few moments with his vicious persecutor sticking so close that the two often seemed like one bat. Finally, they went away out of sight in the distance, and keeping my eyes in the direction they had gone, I saw the big one return alone in about seven or eight minutes and resume his flying up and down with the others. It struck me that if I could have followed or kept them in sight to the finish I should probably have witnessed a little tragedy: the terror of the one and the fury of the other suggested such an end. The keen teeth once fixed in his victim's neck, the noctule would wash his supper of moths and beetles down with a draught of warm blood, then drop the dead body to the earth before returning to his companions. This

is conjecture; but we know that bats have carnivorous propensities, and that in some exotic kinds the big will kill the little, even their own young. Probably they all have something of the vampire in them. The female bat is a most devoted parent, carrying her young about when flying, wrapping them round with her silken wings as with a shawl when in repose, suckling them at her breast even as the highest of the mammalians do. One would not be surprised to learn that the deadliest enemy of her little ones, the one she fears most, is her own consort.

Whether bats migrate or not has long been a moot question, and Millais, our latest authority, and certainly one of the best, has answered it in the affirmative. But the migration he describes is nothing but a change of locality—a retirement from their summer haunts to some spot suitable for hibernation, in some instances but a few miles distant. Other hibernating creatures—serpents, for example—have the same habit, and though compelled to travel on their bellies, they do nevertheless return year after year to the old laying-up places. The question of a seasonal movement in bats, similar to migration in birds, greatly exercised my young mind in former years in a country where bats had no business to be. This was the level, grassy, practically treeless immensity of the pampas, where there were no hollow trunks, nor caves and holes for bats to

shelter in, nor ruins and buildings of brick and stone which would be a substitute for natural caverns. Human dwellings were mostly mud and straw hovels, and the only trees were those planted by man, and were not large and could not grow old. The violent winds swept this floor of the world, which was unsheltered like the sea. Yet punctually in spring the bats appeared along with the later bird migrants, and were common until April, when they vanished, and then for six months no bat would be seen in or out of doors. Clearly, then, they were strictly migratory, able like birds to travel hundreds of miles and to distribute themselves over a vast area. They were, in fact, both migrants and hibernators, since we cannot but suppose that they forsook the pampas only to find some distant place where they could pass their inactive period in safety.

At one point, about two hundred miles south of Buenos Ayres city, the level pampa is broken by a range of stony hills, or sierras, standing above the flat earth like precipitous cliffs that face the sea. On my first visit to that spot I travelled with a party of eight or nine gauchos, and evening coming on near our destination, we camped about a league from the foot of the hills and built a big fire. Just as we had got a good blaze a loud cry of "Morcielagos!" (bats) from one of the men made us look up, and there, overhead, appeared a multitude of bats, attracted by the glare, rush-

ing about in the maddest manner, like a cloud of demented swifts. In a few moments they vanished, and we saw no more of them. Bats, I found, were extremely abundant among these hills, and here they were probably non-migratory.

But the main question about bats is always that of their sense-organs, in which they differ not only from all other mammalians but from all vertebrates, and if in this there is any resemblance or analogue to any other form of life it is to the insect. As to insect senses we are very much in the dark. The number of them may be seven or seventeen, since insects appear to be affected by vibrations which do not touch us. We exist, it has been said, in a bath of vibrations; so do all living things; but in our case the parts by which they enter are few; so too with all other vertebrates except the bat alone, and a puzzle and mystery he remains. What, for example, are the functions of the transverse bands on the wings formed by minute glands; the enormous expanse of ears in the long-eared bat; the earlet, a curious development of the tragus; and the singular leaf-like developments on the nose of the horseshoe bat? We suppose that they are sense-organs, but all we know, or half know, about the matter is ancient history; it dates back to the eighteenth century, when Spallanzani, finding that bats were independent of sight when blinded and set flying in winding tunnels and other confined places,

conjectured that they were endowed with a sixth sense. Cuvier's explanation of these experiments was that the propinquity of solid bodies is perceived by the way in which the air, moved by the pulsations, reacts on the surface of the wings. Thus the sixth sense was a refinement, or extension, of the sense of touch—an excessive sensitiveness in the membrane. Blind men, we know, sometimes have a similar extreme sensibility of the skin of the face. I have known one who was accustomed to spend some hours walking every day in Kensington Gardens, taking short cuts in any direction among the trees and never touching one, and no person seeing him moving so freely about would have imagined that he was totally blind.

My own experiments on bats in South America were inconclusive. I used to collect a dozen or twenty at a time, finding them sleeping by day on the trees in shady places, and after sealing up their eyes with adhesive gum, liberate them in a large room furnished with hanging ropes and objects of various sizes suspended from the rafters. The bats flew about without touching the walls, and deftly avoiding the numerous obstacles; but I soon discovered that they were able when flying to use the hooked claw on the wing to scratch the gum away and pull the eyelids open, and whenever one came to grief I found that its lids had not been opened.

One can see at once that an experiment of this

kind is useless. The irritation of the gum and the efforts being made to remove it by the animal while flying cloud the extra sense or senses, and it loses its efficiency.

What the bat can do I discovered by chance one summer afternoon in an English lane. It was one of those deep Hampshire lanes one finds between Selborne and Prior's Dean, where I was walking just before sunset, when two common bats appeared flying up and down the lane in quest of flies, and always on coming to me they circled round and then made a vicious little stoop at my head as if threatening to strike. My brown and grey striped or mottled tweed caps and hats have often got me into trouble with birds, as I have told in a chapter in *Birds and Man,* and it was probably the colour of my cap on this occasion that excited the animosity of this pair of bats. Again and again I waved my stick over my head on seeing one approach, but it had not the slightest effect—the bat would duck past it and pass over my cap, just grazing it boldly as ever. Then I thought of a way to frighten them. My cane was a slim pliable one, which gave me no support, and was used merely to have something in my hand—a thin little cane such as soldiers carry in their hands off duty. Holding it above my head, I caused it to spin round so rapidly that it was no longer a cane in appearance, but a funel-shaped mist moving with and about me as

I walked. "Now, you little rascal," said I, chuckling to myself as the bat came; then making the usual quick circle he dashed down through the side of the misty obstruction, made his demonstration over my cap, and passed out on the other side. I could hardly credit the evidence of my own eyes, and thought he had escaped a blow by pure luck, and that if he attempted it a second time he would certainly be killed. I didn't want to kill him, but the thing was really too remarkable to be left in doubt, and so I resumed the whirling of the stick over my head, and in another moment the second bat came along, and, like the first, dashed down at my cap, passing in and out of the vortex with perfect ease and safety! Again and again they doubled back and repeated the action without touching the stick, and after witnessing it a dozen or fifteen times I could still hardly believe that their escape from injury was anything but pure chance.

Here I recall the most wonderful flying feat I have witnessed in birds—a very common one. Frequently when standing still among the trees of a plantation or wood where humming-birds abounded, I have had one dart at me, invisible owing to the extreme swiftness of its flight, to become visible—to materialize, as it were—only when it suddenly arrested its flight within a few inches of my face, to remain there suspended motionless like a hover-fly on misty wings that

produced a loud humming sound; and when thus suspended, it has turned its body to the right, then to the left, then completely round as if to exhibit its beauty—its brilliant scale-like feathers changing their colours in the sunlight as it turned. Then, in a few seconds, its curiosity gratified, it has darted away, barely visible as a faint dark line in the air, and vanished perhaps into the intricate branches of some tree, a black acacia perhaps, bristling with long needle-sharp thorns.

The humming-bird is able to perform this feat a hundred times every day with impunity by means of its brilliant vision and the exquisitely perfect judgment of the brilliant little brain behind the sight. But I take it that if the bird had attempted the feat of the bat it would have killed itself.

It is a rule in wild life that nothing is attempted which is not perfectly safe, though to us the action may appear dangerous in the extreme, or even impossible. At all events, I can say that these bats in a Selborne lane taught me more than all the books—they made me see and understand the perfection of that extra sense.

But it is just that same sense which Spallanzani and Cuvier wrote about, and we cannot but think that the bat has something more than this. That peculiar disposition of glands and nerves on the wings, the enormous size of the ear in the great-eared bat, the ear-leaf, and leaf-nose,

and the other developments and excrescences on the face which give to some species a more grotesque countenance than was ever imagined by any medieval artist in stone—these are doubtless all sense-organs, and the question is, are these all additions to the one sense we know of—an extension and refinement of the sense of touch? I think they are more than that, and there are a few facts that incline one to believe that knowledge comes to the bat through more ports than one—knowledge of things far as well as near. One observation made by Millais points to this conclusion. He noticed that a crowd of noctule bats that sheltered in a hollow tree by day, on issuing in the evening all took flight in the same direction, and that the line of flight was not the same, but varied from day to day; that on following them up to the feeding area he discovered that insects were always most abundant at that spot on that evening. It came to this—that on issuing from the hollow tree every bat in the crowd, issuing one or two at a time and flying straight away, knew where to go, south, east, west or north, to some spot a mile or two away. The bat too, then, like the far-seeing vulture, is "sagacious of his quarry from afar," but what Nature has given him in place of his dim, degenerate eyes to make him sagacious in this way remains to be found out.

W. H. HUDSON.

PASTEUR AND THE SILK WORMS

PART I

AN epidemic was ruining in terrible proportions the industry of the cultivation of silkworms. J. B. Dumas had been desired, as Senator, to draw up a report on the wishes of over 3,500 proprietors in sericicultural departments, all begging the public authorities to study the question of the causes of the protracted epidemic. Dumas was all the more preoccupied as to the fate of sericiculture that he himself came from one of the stricken departments. He was born on July 14, 1800, in one of the back streets of the town of Alais, to which he enjoyed returning as a celebrated scientist and a dignitary of the Empire. He gave much attention to all the problems which interested the national prosperity and considered that the best judges in these matters were the men of science. He well knew the conscientious tenacity—besides other characteristics—which his pupil and friend brought into any undertaking, and anxiously urged him to undertake this study. "Your proposition," wrote Pasteur in a few hurried lines, "throws me into a great perplexity; it is indeed most flattering and the object is a high one, but it troubles and embarrasses me!

Remember, if you please, that I have never even touched a silkworm. If I had some of your knowledge on the subject I should not hesitate; it may even come within the range of my present studies. However, the recollection of your many kindnesses to me would leave me bitter regrets if I were to decline your pressing invitation. Do as you like with me." On May 17, 1865, Dumas wrote: "I attach the greatest value to seeing your attention fixed on the question which interests my poor country; the distress is beyond anything you can imagine."

Before his departure for Alais, Pasteur had read an essay on the history of the silkworm, published by one of his colleagues, Quatrefages, born like Dumas in the Gard. Quatrefages attributed to an Empress of China the first knowledge of the art of utilizing silk, more than 4,000 years ago. The Chinese, in possession of the precious insect, had jealously preserved the monopoly of its culture, even to the point of making it a capital offence to take beyond the frontiers of the Empire the eggs of the silkworm. A young princess, 2,000 years later, had the courage to infringe this law for love of her betrothed, whom she was going to join in the centre of Asia, and also through the almost equally strong desire to continue her fairy-like occupation after her marriage.

Pasteur appreciated the pretty legend, but was

more interested in the history of the acclimatizing of the mulberry tree. From Provence Louis XI took it to Touraine: Catherine de Medici planted it in Orléanais. Henry IV had some mulberry trees planted in the park at Fontainebleau and in the Tuileries where they succeeded admirably. He also encouraged a *Treatise on the Gathering of Silk* by Olivier de Serres. This earliest agricultural writer in France was much appreciated by the king, in spite of the opposition of Sully, who did not believe in this new fortune for France. Documentary evidence is lacking as to the development of the silk industry.

From 1700 to 1788, wrote Quatrefages, France produced annually about 6,000,000 kilogrammes of cocoons. This was decreased by one-half under the Republic; wool replaced silk perhaps from necessity, perhaps from affectation.

Napoleon I restored that luxury. The sericicultural industry prospered from the Imperial Epoch until the reign of Louis Philippe, to such an extent as to reach in one year a total of 20,000,000 kilogrammes of cocoons, representing 100,000,000 francs. The name of Tree of Gold given to the mulberry, had never been better deserved.

Suddenly all these riches fell away. A mysterious disease was destroying the nurseries. "Eggs, worms, chrysalides, moths, the disease may manifest itself in all the organs," wrote Dumas in his

report to the Senate. "Whence does it come? how is it contracted? No one knows. But its invasion is recognized by little brown or black spots." It was therefore called "corpuscle disease"; it was also designated as *"gattine"* from the Italian *gattino,* kitten; the sick worms held up their heads and put out their hooked feet like cats about to scratch. But of all those names, that of "pébrine" adopted by Quatrefages was the most general. It came from the patois word *pébrê* (pepper). The spots on the diseased worms were, in fact, rather like pepper grains.

The first symptoms had been noticed by some in 1845, by others in 1847. But in 1849 it was a disaster. The South of France was invaded. In 1853, seed had to be procured from Lombardy. After one successful year the same disappointments recurred. Italy was attacked, also Spain and Austria. Seed was procured from Greece, Turkey, the Caucasus, but the evil was still on the increase; China itself was attacked, and, in 1864, it was only in Japan that healthy seed could be found.

Every hypothesis was suggested, atmospheric conditions, degeneration of the race of silkworms, disease of the mulberry tree, etc.—books and treatises abounded, but in vain.

When Pasteur started for Alais (June 16, 1865), entrusted with this scientific mission by the Minister of Agriculture, his mind saw but

that one point of interrogation, "What caused these fatal spots?" On his arrival he sympathetically questioned the Alaisians. He received confused and contradictory answers, indications of chimerical remedies; some cultivators poured sulphur or charcoal powder on the worms, some mustard meal or castor sugar; ashes and soot were used, quinine powders, etc. Some cultivators preferred liquids, and syringed the mulberry leaves with wine, rum or absinthe. Fumigations of chlorine, of coal tar, were approved by some and violently objected to by others. Pasteur, more desirous of seeking the origin of the evil than of making a census of these remedies, unceasingly questioned the nursery owners, who invariably answered that it was something like the plague or cholera. Some worms languished on the frames in their earliest days, others in the second stage only, some passed through the third and fourth moultings, climbed the twig and spun their cocoon. The chrysalis became a moth, but that diseased moth had deformed antennæ and withered legs, the wings seemed singed. Eggs (technically called seed) from those moths were inevitably unsuccessful the following year. Thus, in the same nursery, in the course of the two months that a larva takes to become a moth, the pébrine disease was alternately sudden or insidious: it burst out or disappeared, it hid itself within the chrysalis and reappeared in the moth or the eggs

of a moth which had seemed sound. The discouraged Alaisians thought that nothing could overcome pébrine.

Pasteur did not admit such resignation. But he began by one aspect only of the problem. He resolved to submit those corpuscles of the silkworm which had been observed since 1849 to microscopical study. He settled down in a small *magnanerie* near Alais; two series of worms were being cultivated. The first set was full grown; it came from some Japanese seed guaranteed as sound, and had produced very fine cocoons. The cultivator intended to keep the seed of the moths to compensate himself for the failure of the second set, also of Japanese origin, but not officially guaranteed. The worms of this second series were sickly and did not feed properly. And yet these worms, seen through the microscope, only exceptionally presented corpuscles; whilst Pasteur was surprised to find some in almost every moth or chrysalis from the prosperous nursery. Was it then elsewhere than in the worms that the secret of the pébrine was to be found?

Pasteur was interrupted in the midst of his experiments by a sudden blow. Nine days after his arrival, a telegram called him to Arbois: his father was very ill. He started, full of anguish, remembering the sudden death of his mother before he had had time to reach her, and that of Jeanne, his eldest daughter, who had also died

far away from him in the little house at Arbois. His sad presentiment oppressed him during the whole of the long journey, and was fully justified; he arrived to find, already in his coffin, the father he so dearly loved and whose name he had made an illustrious one.

On his return to Alais Pasteur went back to his observations with his scientific ardour and his customary generous eagerness to lighten the burden of others.

. . . Pasteur thought with sorrow of the sufferings of the Cévenol populations. The scientific problem was narrowing itself down. Faced by the contradictory facts that one successful set of cocoons had produced corpuscled moths, while an apparently unsuccessful set of worms showed neither corpuscles nor spots, he had awaited the last period of these worms with an impatient curiosity. He saw, amongst those which had started spinning, some which as yet showed no spots and no corpuscles. But corpuscles were abundant in the chrysalides, those especially which were in full maturity, on the eve of becoming moths; and none of the moths were free from them. Perhaps the fact that the disease appeared in the chrysalis and moth only explained the failures of succeeding series. "It was a mistake," wrote Pasteur (June 26, 1865), "to look for the symptom, the corpuscle, exclusively in the eggs or the worms; either might carry in themselves the

germ of the disease, without presenting distinct and microscopically visible corpuscles. The evil developed itself chiefly in the chrysalides and the moths, it was there that it should chiefly be sought. There should be an infallible means of procuring healthy seed by having recourse to moths free from corpuscles."

This idea was like a searchlight flashed into the darkness. Pasteur thus formulated his hypothesis: "Every moth containing corpuscles must give birth to diseased seed. If a moth only has a few corpuscles, its eggs will provide worms without any, or which will only develop them towards the end of their life. If the moth is much infected, the disease will show itself in the earliest stages of the worm, either by corpuscles or by other unhealthy symptoms."

Pasteur studied hundreds of moths under the microscope. Nearly all, two or three couples excepted, were corpuscled, but that restricted quantity was increased by a precious gift. Two people, who had heard Pasteur ventilate his theories, brought him five moths born of a local race of silkworms and nurtured in the small neighbouring town of Anduze in the Turkish fashion, i.e. without any of the usual precautions consisting in keeping the worms in nurseries heated at an equal temperature. Everything having been tried, this system had also had its turn, without any appreciable success. By a fortunate circumstance,

four out of those five moths were healthy.

Pasteur looked forward to the study in comparisons that the following spring would bring when worms were hatched both from the healthy and the diseased seed. In the meanwhile, only a few of the Alaisians, including M. Pagès, the Mayor, and M. de Lachadenède, really felt any confidence in these results. Most of the other silkworm cultivators were disposed to criticize everything, without having the patience to wait for results. They expressed much regret that the Government should choose a "mere chemist" for those investigations instead of some zoologist or silkworm cultivator. Pasteur only said, "Have patience."

What he most wished was to be able to watch the growth of the silkworms from the very first day, and to pursue without interruption this serious study in which the future of France was interested. That, and the desire to have one day a laboratory adequate to the magnitude of his works were his only ambitions. On his return to Paris he obtained leave to go back to Alais.

"My dear Raulin," wrote Pasteur to his former pupil in January, 1866. "I am again entrusted by the Minister of Agriculture with a mission for the study of silkworm disease, which will last at least five months, from February 1 to the end of June. Would you care to join me?"

Raulin excused himself; he was then prepar-

ing, with his accustomed slow conscientiousness, his doctor's thesis, a work afterwards considered by competent judges to be a masterpiece.

. . . One of Raulin's fellow students at the Ecole Normale, M. Gernez, was now a professor at the Collège Louis le Grand. His mind was eminently congenial to Pasteur's. Duruy, then Minister of Public Instruction, was ever anxious to smooth down all difficulties in the path of science: he gave a long leave of absence to M. Gernez, in order that he might take Raulin's place. Another young *Normalien,* Maillot, prepared to join the scientific party, much to his delight. The three men left Paris at the beginning of February. They began by spending a few days in an hotel at Alais, trying to find a suitable house where they would set up their temporary laboratory. After a week or two in a house within the town, too far, to be convenient, from the restaurant where they had their meals, Maillot discovered a lonely house at the foot of the Mount of the Hermitage, a mountain once covered with flourishing mulberry trees, but now abandoned, and growing but a few olive trees.

This house, at Pont Gisquet, not quite a mile from Alais, was large enough to hold Pasteur, his family and his pupils; a laboratory was soon arranged in an empty orangery.

"Then began a period of intense work," writes M. Gernez. "Pasteur undertook a great number

of trials, which he himself followed in their minutest details; he only required our help over similar operations by which he tested his own. The result was that above the fatigues of the day, easily borne by us strong young men, he had to bear the additional burden of special researches, importunate visitors, and an equally importunate correspondence, chiefly dealing out criticisms. . . ."

Madame Pasteur, who had been detained in Paris for her children's education, set out for Alais with her two daughters. Her mother being then on a visit to the rector of the Chambéry Academy, M. Zevort, she arranged to spend a day or two in that town. But hardly had she arrived when her daughter Cécile, then twelve years old, became ill with typhoid fever. Madame Pasteur had the courage not to ask her husband to leave his work and come to her; but her letters alarmed him, and the anxious father gave up his studies for a few days and arrived at Chambéry. The danger at that time seemed averted, and he only remained three days at Chambéry. Cécile, apparently convalescent, had recovered her smile, that sweet, indefinable smile which gave so much charm to her serious, almost melancholy face. She smiled thus for the last time at her little sister Marie-Louise, about the middle of May, lying on a sofa by a sunny window.

On May 21, her doctor, Dr. Flesschutt, wrote

to Pasteur: "If the interest I take in the child were not sufficient to stimulate my efforts, the mother's courage would keep up my hopes and double my ardent desire for a happy issue." Cécile died on May 23 after a sudden relapse. Pasteur only arrived at Chambéry in time to take to Arbois the remains of the little girl, which were buried near those of his mother, of his two other daughters, Jeanne and Camille, and of his father, Joseph Pasteur. The little cemetery indeed represented a cup of sorrows for Pasteur.

"Your father has returned from his sad journey to Arbois," wrote Madame Pasteur from Chambéry to her son who was at school in Paris. "I did think of going back to you, but I could not leave your poor father to go back to Alais alone after this great sorrow." Accompanied by her who was his greatest comfort, and who gavè him some of her own courage, Pasteur came back to the Pont Gisquet and returned to his work. M. Duclaux in his turn joined the hard-working little party.

At the beginning of June, Duruy, with the solicitude of a Minister who found time to be also a friend, wrote affectionately to Pasteur—

"You are leaving me quite in the dark, yet you know the interest I take in your work. Where are you? and what are you doing? Finding out something I feel certain. . . ."

Pasteur answered, ". . . I am arriving at this result that there is no silkworm disease. There is but an exaggeration of a state of things which has always existed, and it is not difficult, in my view, to return to the former situation, even to improve on it. The evil was sought for in the worm and even in the seed; that was something, but my observations prove that it develops chiefly in the chrysalis, especially in the mature chrysalis, at the moment of the moth's formation, on the eve of the function of reproduction. The microscope then detects its presence with certitude, even when the seed and the worm seem very healthy. The practical result is this: you have a nursery full; it has been successful or it has not; you wish to know whether to smother the cocoons or whether to keep them for reproduction. Nothing is simpler. You hasten the development of about 100 moths through an elevation of temperature, and you examine these moths through the microscope, which will tell you what to do.

"The sickly character is then so easy to detect that a woman or a child can do it. If the cultivator should be a peasant, without the material conditions required for this study, he can do this: instead of throwing away the moths after they have laid their eggs, he can bottle a good many of them in brandy and send them to a testing office or to some experienced person who will

determine the value of the seed for the following year."

The Japanese Government sent some cases of seed supposed to be healthy to Napoleon III, who distributed them in the silkworm growing departments. Pasteur, in the meanwhile, was stating the results he had arrived at, and they were being much criticized. In order to avoid the pébrine, which was indeed the disease caused by the corpuscles so clearly visible through the microscope, he averred that no seed should be used that came from infected moths. In order to demonstrate the infectious character of the pébrine he would give to some worms meals of leaves previously contaminated by means of a brush dipped in water containing corpuscles. The worms absorbed the food, and the disease immediately appeared and could be found in the chrysalides and moths from those worms.

"I hope I am in the right road—close to the goal, perhaps, but I have not yet reached it," wrote Pasteur to his faithful Chappuis; "and as long as the final proof is not acquired complications and errors are to be feared. Next year, the growth of the numerous eggs I have prepared will obviate my scruples, and I shall be sure of the value of the preventive means I have indicated. It is tiresome to have to wait a year before testing observations already made; but I have every hope of success."

While awaiting the renewal of the silkworm season, he was busy editing his book on wine, full of joy at contributing to the national riches through practical application of his observations. Pasteur, who had confidently said, "The year 1867 must be the last to bear the complaints of silkworm cultivators!" went back to Alais in January, 1867. But, before leaving Paris, Pasteur wrote out for himself a list of various improvements and reforms which he desired to effect in the administration of the Ecole Normale, showing that his interest in the great school had by no means abated, in spite of his necessary absence. He brought with him his wife and daughter, and Messrs. Gernez and Maillot; M. Duclaux was to come later. The worms hatched from the eggs of healthy moths and those from diseased ones were growing more interesting every day; they were in every instance exactly what Pasteur had prophesied they would be. But besides studying his own silkworms, he liked to see what was going on in neighbouring *magnaneries*. A neighbour in the Pont Gisquet, a cultivator of the name of Cardinal, had raised with great success a brood originating from the famous Japanese seed. He was disappointed, however, in the eggs produced by the moths, and Pasteur's microscope revealed the fact that those moths were all corpuscled, in spite of their healthy origin. Pasteur did not suspect that origin, for the worms had shown

health and vigour through all their stages of growth, and seemed to have issued from healthy parents. But Cardinal had raised another brood, the produce of unsound seed, immediately above these healthy worms. The excreta from this second brood could fall on to the frames of those below them, and the healthy worms had become contaminated. Pasteur demonstrated that the pébrine contagion might take place in one or two different ways: either from direct contact between the worms on the same frame, or by the soiling of the food from the very infectious excreta. The remedy for the pébrine seemed now found. "The corpuscle disease," said Pasteur, "is as easily avoided as it is easily contracted." But when he thought he had reached his goal a sudden difficulty rose in his way. Out of sixteen broods of worms which he had raised, and which presented an excellent appearance, the sixteenth perished almost entirely immediately after the first moulting. "In a brood of a hundred worms," wrote Pasteur, "I picked up fifteen or twenty dead ones every day, black and rotting with extraordinary rapidity. . . . They were soft and flaccid like an empty bladder. I looked in vain for corpuscles; there was not a trace of them."

Pasteur was temporarily troubled and discouraged. But he consulted the writings of former students of silkworm diseases, and, when he discovered vibriones in those dead worms, he did not

doubt that he had under his eyes a well characterized example of the flachery disease—a disease independent and distinct from the pébrine.

In May, 1867, Pasteur received at Alais the news that a grand prize medal of the 1867 exhibition was conferred upon him for his works on wines. He hastened to write to Dumas—

"My dear master, . . . Nothing has surprised me more—or so agreeably,—than the news of this Exhibition prize medal, which I was far from expecting. It is a new proof of your kindness, for I feel sure that I have to thank you for originating such a favour. I shall do all I can to make myself worthy of it by my perseverance in putting all difficulties aside from the subject I am now engaged in, and in which the light is growing brighter every day. If that flachery disease had not come to complicate matters, everything would be well by now. I cannot tell you how absolutely sure I now feel of my conclusions concerning the corpuscle disease. I could say a great deal about the articles of Messrs. Béchamp, Estor and Balbiani, but I will follow your advice and answer nothing . . ."

Dumas had been advising Pasteur not to waste his time by answering his adversaries and contradictors. Pasteur's system was making way; ten microscopes were set up, here and there, in the town of Alais; most seed merchants were taking up the examination of the dead moths, and

the Pont-Gisquet colony had samples brought in daily for inspection. "I have already prevented many failures for next year," he wrote to Dumas (June, 1867), "but I always beg as a favour that a little of the condemned seed may be raised, so as to confirm the exactness of my judgment."

His system was indeed quite simple; at the moment when the moths leave their cocoons and mate with each other, the cultivator separates them and places each female on a little square of linen where it lays its eggs. The moth is afterwards pinned up in a corner of the same square of linen, where it gradually dries up; later on, in autumn or even in winter, the withered moth is moistened in a little water, pounded in a mortar, and the paste examined with a microscope. If the least trace of corpuscles appears the linen is burnt, together with the seed which would have perpetuated the disease.

Pasteur came back to Paris to receive his medal; perhaps his presence was not absolutely necessary, but he did not question the summons he received. He always attached an absolute meaning to words and to things, not being one of those who accept titles and homage with an inward and ironical smile.

On his return to his study in the Rue d'Ulm, Pasteur again took up the management of the scientific studies of the Ecole Normale. But an incident put an end to his directorship, while

bringing perturbation into the whole of the school. Sainte Beuve was the indirect cause of this small revolution. The Senate, of which he was a member, had had to examine a protest from 102 inhabitants of St. Etienne against the introduction into their popular libraries of the works of Voltaire, J. J. Rousseau, Balzac, E. Renan, and others. The committee had approved this petition in terms which identified the report with the petition itself. Sainte Beuve, too exclusively literary in his tastes, and too radical in his opinions to be popular in the Senate, rose violently against this absolute and arbitrary judgment, forgetting everything but the jeopardy of free opinions before the excessive and inquisitorial zeal of the Senate. His speech was very unfavourably received, and one of his colleagues, M. Lacaze, aged sixty-eight, challenged him to a duel. Sainte Beuve, himself then sixty-three years old, refused to enter into what he called "the summary jurisprudence which consists in strangling a question and suppressing a man within forty-eight hours."

The students of the Ecole Normale deputed one of their number to congratulate Sainte Beuve on his speech, and wrote the following letter—

"We have already thanked you for defending freedom of thought when misjudged and attacked; now that you have again pleaded for it, we beg you to receive our renewed thanks.

"We should be happy if the expression of our grateful sympathy could console you for this injustice. Courage is indeed required to speak in the Senate in favour of the independence and the rights of thought; but the task is all the more glorious for being more difficult. Addresses are now being sent from everywhere; you will forgive the students of the Ecole Normale for having followed the general lead and having sent their addresses to M. Sainte Beuve."

This letter was published in a newspaper. Etienne Arago published it without remembering the Université by-laws which forbade every sort of political manifestation to the students. It had given pleasure to Sainte Beuve, the pleasure that elderly men take in the applause of youth; but he soon became uneasy at the results of this noisy publicity.

Nisard, the Director of the school, could not very well tolerate this breach of discipline. In spite of the entreaties of Sainte Beuve, the student who had signed the letter was provisionally sent back to his family. His comrades revolted at this and imperiously demanded his immediate restoration. Pasteur attempted to pacify them by speaking to them, but failed utterly; his influence was very great over his own pupils, the students on the scientific side, but the others, the *"littéraires,"* were the most violent on this question, and he

was not diplomatic and conciliating enough to bring them round. They rose in a body, marched to the door, and the whole school was soon parading the streets. "Before such disorder," concluded the *Moniteur,* relating the incident (July 10), "the authorities were obliged to order an immediate closure. The school will be reconstituted and the classes will reopen on October 15."

Both the literary and the political world were temporarily agitated; the Minister was interviewed. M. Thiers wrote to Pasteur on July 10: "My dear M. Pasteur,—I have been talking with some members of the Left, and I am certain or almost certain, that the Ecole Normale affair will be smoothed over in the interest of the students. M. Jules Simon intends to work in that direction; keep this information for yourself, and do the best you can on your side."

At the idea that the Ecole was about to be reconstituted, that is, that the three great chiefs, Nisard, Pasteur and Jacquinet, would be changed, deep regret was manifested by Pasteur's scientific students. One of them, named Didon, expressed it in these terms: "If your departure from the school is not definitely settled, if it is yet possible to prevent it, all the students of the Ecole will be only too happy to do everything in their power. . . . As for me, it is impossible to express my gratitude towards you. No one has

ever shown me so much interest, and never in my life shall I forget what you have done for me."

Pasteur's interest in young men, his desire to excite in them scientific curiosity and enthusiasm, were now so well known that Didon and several others who had successfully passed the entrance examinations both for the Ecole Polytechnique and the Ecole Normale, had chosen to enter the latter in order to be under him; by the *Normaliens* of the scientific section, he was not only understood and admired, but beloved, almost worshipped.

Sainte Beuve, who continued to be much troubled at the consequences of his speech, wrote to the Minister of Public Instruction in favour of the rusticated student. Duruy thought so much of Sainte Beuve that the student, instead of being exiled to some insignificant country school, was made professor of *seconde* in the college of Sens. But it was specified that in the future no letter should be written, no public responsibility taken in the name of the Ecole without the authorization of the Director.

Nisard left; Dumas had just been made President of the Monetary Commission, thus leaving vacant a place as Inspector-General of Higher Education. Duruy, anxious to do Pasteur justice, thought this post most suitable to him as it would allow him to continue his researches. The decree

was about to be signed, when Balard, professor of chemistry at the Faculty of Sciences applied for the post. Pasteur wrote respectfully to the Minister of Public Instruction (July 31): "Your Excellency must know that twenty years ago, when I left the Ecole Normale, I was made a curator, thanks to M. Balard, who was then a professor at the Ecole Normale. A grateful pupil cannot enter into competition with a revered master, especially for a post where considerations of age and experience should have great weight."

When Pasteur spoke of his masters, dead or living, Biot or Senarmont, Dumas or Balard, it might indeed have been thought that to them alone he owed it that he was what he was. He was heard on this occasion, and Balard obtained the appointment.

Nisard was succeeded by M. F. Bouillier, whose place as Inspector-General of Secondary Education devolved on M. Jacquinet. The directorship of scientific studies was given to Pasteur's old and excellent friend, the faithful Bertin. After teaching in Alsace for eighteen years, he had become *maître des conférences* at the Ecole Normale in 1866, and also assistant of Regnault at the Collège de France. It had only been by dint of much persuasion that Pasteur had enticed him to Paris. "What is the good?" said the unambitious Bertin; "beer is not so good in Paris as in Strasburg. . . . Pasteur does

not understand life; he is a genius, that is all! But, under this apparent indolence, Bertin w possessed of the taste for and the art of teachin Pasteur knew this, and, when Bertin was a pointed, Pasteur's fears for the scientific futu of his beloved Ecole were abated. Duruy, muc regretting the break of Pasteur's connection wi the great school, offered him the post of *maît des conférences,* besides the chair of chemist which Balard's appointment had left vacant the Sorbonne. But Pasteur declined the temptir offer; he knew the care and trouble that his pu lic lectures cost him, and felt that the two pos would be beyond his strength; if his time we taken up by that double task it would be almo impossible for him to pursue his private r searches, which under no circumstances would l abandon.

He carried his scruples so far as to give up h chemistry professorship at the School of Fi Arts, where he had been lecturing since 186 He had endeavoured in his lessons to draw t attention of his artist pupils, who came from many distant places, to the actual principles Science. "Let us always make application o object," he said, "but resting on the stern a solid basis of scientific principles. Without tho principles, application is nothing more than series of recipes and constitutes what is call

routine. Progress with routine is possible, but desperately slow."

Another reason prevented him from accepting the post offered him at the Ecole Normale; this was that the tiny pavilion which he had made his laboratory was much too small and too inconvenient to accommodate the pupils he would have to teach. The only suitable laboratory at the Ecole was that of his friend, Henri Sainte Claire Deville, and Pasteur was reluctant to invade it. He had a great affection for his brilliant colleague, who was indeed a particularly charming man, still youthful in spite of his forty-nine summers, active, energetic, witty. "I have no wit," Pasteur would say quite simply. Deville was a great contrast to his two great friends, Pasteur and Claude Bernard, with their grave meditative manner. He enjoyed boarding at the Ecole and having his meals at the students' table, where his gaiety brightened and amused everybody, effacing the distance between masters and pupils and yet never losing by this familiar attitude a particle of the respect he inspired.

Sometimes, however, when preoccupied with the heavy expenses of his laboratory, he would invite himself to lunch with Duruy, from whom—as from the Emperor or any one else—he usually succeeded in coaxing what he wanted. The general state of things connected with higher educa-

tion was at that time most deplorable. The Sorbonne was as Richelieu had left it—the Museum was sadly inadequate. At the Collège de France, it was indeed impossible to call by the name of laboratory the narrow, damp and unhealthy cellars, which Claude Bernard called "scientists' graves," and where he had contracted the long illness from which he was only just recovering.

Duruy understood and deplored this penury, but his voice was scarcely heard in cabinet councils, the other Ministers being absorbed in politics. Pasteur, whose self-effacing modesty disappeared when the interests of science were in question, presented to Napoleon, through the medium of his enlightened aide de camp, General Favé, the following letter, a most interesting one, for, in it, possibilities of future discoveries are hinted at, which later became accomplished facts.

"Sire,—My researches on fermentations and on microscopic organisms have opened to physiological chemistry new roads, the benefit of which is beginning to be felt both by agricultural industries and by medical studies. But the field still to be explored is immense. My great desire would be to explore it with a new ardour, unrestrained by the insufficiency of material means.

"I should wish to have a spacious laboratory, with one or two outhouses attached to it, which I could make use of when making experiments possibly injurious to health, such as might be the

scientific study of putrid and infectious diseases.

"How can researches be attempted on gangrene, virus or inoculations, without a building suitable for the housing of animals, either dead or alive? Butchers' meat in Europe reaches an exorbitant price, in Buenos Ayres it is given away. How, in a small and incomplete laboratory, can experiments be made, and various processes tested, which would facilitate its transport and preservation? The so-called 'splenic fever' costs the Beauce * about 4,000,000 francs annually; it would be indispensable to go and spend some weeks in the neighbourhood of Chartres during several consecutive summers, and make minute observations.

"These researches and a thousand others which correspond in my mind to the great act of transformation after death of organic matter, and the compulsory return to the ground and atmosphere of all which has once been living, are only compatible with the installation of a great laboratory. The time has now come when experimental science should be freed from its bonds . . ."

The Emperor wrote to Duruy the very next day, desiring that Pasteur's wish should be acceded to. Duruy gladly acquiesced and plans be-

* Ancient name of the high flat ground surrounding Chartres and including parts of the Departments of Eure et Loir, Loir et Cher, Loiret and Seine et Oise. These plains are very fertile, the soil being extremely rich, and produce cereals chiefly. [Trans.]

gan to be drawn out. Pasteur, who scarcely dared believe in these bright hopes, was consulted about the situation, size, etc., of the future building, and looked forward to obtaining the help of Raulin, his former pupil, when he had room enough to experiment on a larger scale. The proposed site was part of the garden of the Ecole Normale, where the pavilion already existing could be greatly added to.

On March 10, [1868] Pasteur started for Alais, where his arrival was impatiently awaited, both by partisans and adversaries of his experiments on silkworm disease.

On his arrival he found to his joy that those who had practised seeding according to his rigorous prescriptions had met with complete success. Other silkworm cultivators, less well advised, duped by the decoying appearances of certain broods, had not taken the trouble to examine whether the moths were corpuscled; they were witnesses and victims of the failure Pasteur had prophesied. He now looked upon pébrine as conquered; but flachery remained, more difficult to prevent, being greatly dependent upon those accidents which traverse the life of a silkworm. Some of those accidents happen in spite of all precautions, such as a sudden change of temperature or a stormy day; but at least the leaves of the mulberry tree could be carefully kept from

fermentation, or from contamination by dusts in the nurseries. Either of those two causes was sufficient to provoke a fatal disorder in silkworms, the feeding of which is so important that they increase to fifteen thousand times their own weight during the first month of their life. Accidental flachery could therefore be avoided by hygienic precautions. In order to prevent it from becoming hereditary, Pasteur—who had pointed out that the micro-organism which causes it develops at first in the intestinal canal of the worm and then becomes localized in the digestive cavity of the chrysalis—advised the following means of producing a healthy strain of silkworms: "This means," writes M. Gernez, Pasteur's assiduous collaborator in these studies, "does not greatly complicate operations, and infallibly ensures healthy seed. It consists in abstracting with the point of a scalpel a small portion of the digestive cavity of a moth, then mixing it with a little water and examining it with a microscope. If the moths do not contain the characteristic micro-organism, the strain they come from may unhesitatingly be considered as suitable for seeding. The flachery micro-organism is as easily recognized as the pébrine corpuscle."

The seed merchants, made uneasy by these discoveries which so gravely jeopardized their industry, spread the most slanderous reports about them and made themselves the willing echo of

every imposture, however incredible. M. Laurent wrote to his daughter, Madame Pasteur, in a letter dated from Lyons (June 6): "It is being reported here that the failure of Pasteur's process has excited the population of your neighbourhood so much that he has had to flee from Alais, pursued by infuriated inhabitants throwing stones after him." Some of these legends lingered in the minds of ignorant people.

Pasteur's life was now over full. He returned to Paris at the beginning of October, and threw himself into his work, his classes at the Sorbonne, the organization of his laboratory, some further polemics on the subject of silkworm disease, and projected experiments for the following year. This accumulation of mental work brought about extreme cerebral tension.

As soon as he saw M. Gernez, he spoke to him of the coming campaign of sericiculture, of his desire to reduce his adversaries to silence by heaping proof upon proof. Nothing could relieve him from that absorbing preoccupation, not even the gaiety of Bertin, who, living on the same floor at the Ecole Normale, often used to come in after dinner and try to amuse him.

On Monday, October 19, Pasteur, though suffering from a strange tingling sensation of the left side, had a great desire to go and read to the Académie des Sciences a treatise by Salimbeni, an Italian, who, having studied and verified Pas-

teur's results, declared that the best means of regenerating the culture of silkworms was due to the French scientist. This treatise, the diploma of the Bonn University, the Rumford medal offered by the English, all those testimonials from neighbouring nations were infinitely agreeable to Pasteur, who was proud to lay such homage before the shrine of France. On that day, October 19, 1868, a date which became a bitter memory to his family and friends—in spite of an alarming shivering fit which had caused him to lie down immediately after lunch instead of working as usual—he insisted on going to the Academy sitting at half past two.

Mme. Pasteur, vaguely uneasy, made a pretext of some shopping beyond the Quai Conti and accompanied him as far as the vestibule of the Institute. As she was turning back, she met Balard, who was coming up with the quick step of a young man, stopped him and asked him to walk back with Pasteur, and not to leave him before reaching his own door, though indeed it seemed a curious exchange of parts to ask Balard at sixty years of age to watch over Pasteur still so young. Pasteur read Salimbeni's paper in his usual steady voice, remained until the end of the sitting and walked back with Balard and Sainte Claire Deville. He dined very lightly and went to bed at nine o'clock; he had hardly got into bed when he felt himself attacked by the strange symptoms of

the afternoon. He tried to speak, but in vain; after a few moments he was able to call for assistance. Mme. Pasteur sent at once for Dr. Godélier, an intimate friend of the family, an army surgeon, Clinical Professor at the Ecole du Val-de-Grâce;* and Pasteur, paralysed one moment and free again the next, explained his own symptoms during the intervals of the dark struggle which endangered his life.

The cerebral hæmorrhage gradually brought about absence of movement along the entire left side. When the next morning Dr. Noël Gueneau de Mussy, going his regulation round of the Ecole Normale students, came into his room and said, so as not to alarm him, "I heard you were unwell, and thought I would come to see you," Pasteur smiled the sad smile of a patient with no illusions. Drs. Godélier and Gueneau de Mussy decided to call Dr. Andral in consultation, and went to fetch him at three o'clock at the Académie de Médecine. Somewhat disconcerted by the singular character of this attack of hemiplegia, Andral prescribed the application of sixteen leeches behind the ears; blood flowed abundantly, and Dr. Godélier wrote in the evening bulletin (Tuesday): "Speech clearer, some movements of the paralysed limbs; intelligence perfect." Later, at ten o'clock: "Complains of his

* *Val-de-Grâce.* A handsome monument of the seventeenth century, now a military hospital. [Trans.]

paralysed arm." "It is like lead; if it could only be cut off!" groaned Pasteur. About 2 a.m. Mme. Pasteur thought all hope was gone. The hastily written bulletin reads thus: "Intense cold, anxious agitation, features depressed, eyes languid." The sleep which followed was as the sleep of death.

At dawn Pasteur awoke from this drowsiness. "Mental faculties still absolutely intact," wrote M. Godélier at 12.30 on Wednesday, October 21. "The cerebral lesion, whatever it may be, is not worse; there is an evident pause." Two hours later the words, "Mind active," were followed by the startling statement, "Would willingly talk science."

While these periods of calm, agitation, renewed hopes, and despair were succeeding each other in the course of those thirty-six hours, Pasteur's friends hastened to his bedside. He said to Henri Sainte Claire Deville, one of the first to come: "I am sorry to die; I wanted to do much more for my country." Sainte Claire Deville, trying to hide his grief under apparent confidence, answered, "Never fear; you will recover, you will make many more marvellous discoveries, you will live happy days; I am your senior, you will survive me. Promise me that you will pronounce my funeral oration. . . . I wish you would; you would say nice things of me," he added between tears and smiles.

Bertin, Gernez, Duclaux, Raulin, Didon, then a curator at the Ecole Normale, Professor Auguste Lamy, the geologist Marcou (the two latter being Franche-comté friends), all claimed the privilege of helping Mme. Pasteur and M. Godélier in nursing one who inspired them all, not merely with an admiring and devoted affection, but with a feeling of tenderness amounting almost to a cult.

. . . M. Pasteur's mind remained clear, luminous, dominating his prostrate body; he was evidently afraid that he should die before having thoroughly settled the question of silkworm diseases. "One night that I was alone with him," relates M. Gernez, who hardly left his bedside during that terrible week, "after endeavouring in vain to distract his thoughts, I despairingly gave up the attempt and allowed him to express the ideas which were on his mind; finding, to my surprise, that they had his accustomed clearness and conciseness, I wrote what he dictated without altering a word, and the next day I brought to his illustrious colleague, Dumas—who hardly credited his senses—the memorandum which appeared in the report of the Académie on October 26, 1868, a week after the stroke which nearly killed him! It was a note on a very ingenious process for discovering in the earlier tests those eggs which are predisposed by flachery."

The members of the Academy were much

cheered by the reading of this note, which seemed to bring Pasteur back into their midst.

The building of the laboratory had been begun, and hoardings erected around the site. Pasteur, from his bed, asked day by day, "How are they getting on?" But his wife and daughter, going to the window of the dining-room which overlooked the Ecole Normale garden, only brought him back vague answers, for, as a matter of fact, the workmen had disappeared from the very first day of Pasteur's illness. All that could be seen was a solitary labourer wheeling a barrow aimlessly about, probably under the orders of some official who feared to alarm the patient.

As Pasteur was not expected to recover, the trouble and expense were deemed unnecessary. Pasteur soon became aware of this, and one day that General Favé had come to see him he gave vent to some bitter feelings as to this cautious interruption of the building works, saying that it would have been simpler and more straightforward to state from the beginning that the work was suspended in the expectation of a probable demise.

Napoleon was informed of this excess of zeal, not only by General Favé, but by Sainte Claire Deville, who was a guest at Compiègne at the beginning of November, 1868. He wrote to the Minister of Public Instruction—

"My dear M. Duruy,—I have heard that—

unknown to you probably—the men who were working at M. Pasteur's laboratory were kept away from the very day he became ill; he has been much affected by this circumstance, which seemed to point to his non-recovery. I beg you will issue orders that the work should be continued. Believe in my sincere friendship.—Napoleon."

. . . It was only on November 30 that Pasteur left his bed for the first time and spent an hour in his armchair. He clearly analysed to himself his melancholy condition, stricken down as he was by hemiplegia in his forty-sixth year; but having noticed that his remarks saddened his wife and daughter, he spoke no more about his illness, and only expressed his anxiety not to be a trouble, a burden, he said, to his wife, his son and daughter, and the devoted friends who helped to watch him at night.

With December, joy began to return to the Ecole Normale: the laboratory was progressing and seemed an embodiment of renewed hopes of further work. M. Godélier's little bulletins now ran: "General condition most satisfactory. Excellent morale; the progress evidenced daily by the return of action in the paralysed muscles inspires the patient with great confidence. He is planning out his future sericiculture campaign, receives many callers without too much fatigue, converses brightly and often dictates letters."

The bulletins continued to be favourable: "(December 15): Progress slow but sure: he has walked from his bed to his armchair with some assistance. (December 22): he has gone into the dining-room for dinner, leaning on a chair. (29th): he has walked a few steps without support."

Pasteur saw in his convalescence but the returning means of working, and declared himself ready to start again for the neighbourhood of Alais at once, instead of taking the few months' rest he was advised to have.

He urged that, after certain moths and chrysalides, had been examined through a microscope, complete certainty would be acquired as to the condition of their seed, and that perfect seed would therefore become accessible to all tradesmen both great and small; would it not be absurd and culpable to let reasons of personal health interfere with saving so many poor people from ruin?

His family had to give way, and on January 18, exactly three months after his paralytic stroke, he was taken to the *Gare de Lyon* by his wife and daughter and M. Gernez. He then travelled, lying on the cushions of a *coupé* carriage, as far as Alais, and drove from Alais to St. Hippolyte le Fort, where tests were being made on forced silkworms by the agricultural society of Le Vigan.

The house he came into was cold and badly arranged. M. Gernez improvised a laboratory, with the assistance of Maillot and Raulin, who had followed their master down. From his sofa or from his bed, Pasteur directed certain experiments on the forced specimens. M. Gernez writes: "The operations, of which we watched the phases through the microscope, fully justified his anticipations; and he rejoiced that he had not given up the game." In the world of the Institute his departure was blamed by some and praised by others; but Pasteur merely considered that one man's life is worthless if not useful to others.

Dumas wrote to him early in February: "My dear friend and colleague,—I have been thinking of you so much! I dread fatigue for you, and wish I could spare it you, whilst hoping that you may successfully achieve your great and patriotic undertaking. I have hesitated to write to you for fear you should feel obliged to answer. However, I should like to have direct news of you, as detailed as possible, and, besides that, I should be much obliged if you could send me a line to enlighten me on the two following points—

"1. When are you going back to Alais? And when will your Alais broods be near enough to their time to be most interesting to visit?

"2. What should I say to people who beg for healthy seed as if my pockets were full of it? I

tell them it is too late; but if you could tell me a means of satisfying them, I should be pleased, particularly in the case of General Randon and M. Husson. The Marshal (Vaillant) is full of solicitude for you, and we never meet but our whole conversation turns upon you. With me, it is natural. With him less so, perhaps, but anyhow, he thinks of you as much as is possible, and this gives me a great deal of pleasure. . . . Please present to Madame Pasteur our united compliments and wishes. We wish the South could have the virtues of Achilles' lance—of healing the wounds it has caused.—Yours affectionately."

Pasteur was reduced to complete helplessness through having slipped and fallen on the stone floor of his uncomfortable house, and was obliged to dictate the following letter—

"My dear master,—I thank you for thinking of the poor invalid. I am very much in the same condition as when I left Paris, my progress having been retarded by a fall on my left side. Fortunately, I sustained no fracture, but only bruises, which were naturally painful and very slow to disappear.

"There are now no remaining traces of that accident, and I am as I was three weeks ago. The improvement in the movements of the leg and arm appears to have begun again, but with excessive slowness. I am about to have recourse to electricity, under the advice and instructions of

Dr. Godélier, by means of a small Ruhmkorff apparatus which he has kindly sent me. My brain is still very weak.

"This is how my days are spent: in the morning my three young friends come to see me, and I arrange the day's work. I get up at twelve, after having my breakfast in bed, and having had the newspaper read to me. If fine, I then spend an hour or two in the little garden of this house. Usually, if I am feeling pretty well, I dictate to my dear wife a page, or more frequently half a page, of a little book I am preparing, and in which I intend to give a short account of the whole of my observations. Before dinner, which I have alone with my wife and my little girl in order to avoid the fatigue of conversation, my young collaborators bring me a report of their work. About seven or half past, I always feel terribly tired and inclined to sleep twelve consecutive hours; but I invariably wake at midnight, not to sleep again until towards morning, when I doze again for an hour or two. What makes me hope for an ultimate cure is the fact that my appetite keeps good, and that those short hours of sleep appear to be sufficient. You see that on the whole I am doing nothing rash, being moreover rigorously watched by my wife and little daughter. The latter pitilessly takes books, pens, papers and pencils away from me with a perseverance which causes me joy and despair.

"It is because I know your affection for your pupils that I venture to give you so many details. I will now answer the other questions in your letter.

"I shall be at Alais from April 1; that will be the time when they will begin hatching seed for the industrial campaign, which will consequently be concluded about May 20 at the latest. Seeding will take place during June, more or less early according to departments. It is indeed very late to obtain seed, especially indigenous seed prepared according to my process. I had foreseen that I should receive demands at the last moment, and that I should do well to put by a few ounces; but, about three weeks ago, our energetic Minister wrote to ask me for some seed to distribute to schoolmasters, and I promised him what I had. However I will take some from his share and send you several lots of five grammes. The director of a most interesting Austrian establishment has also ordered two ounces, saying he is convinced of the excellence of my method. His establishment is a most interesting experimental *magnanerie*, founded in a handsome Illyrian property. Lastly, I have also promised two ounces to M. le Comte de Casabianca. One of my young men is going out to his place in Corsica to do the seeding.

"I was much touched by what you tell me of Marshal Vaillant's kind interest in my health,

and also by his kind thought in informing me of the encouragement given to my studies by the Society of Agriculture. I wish the cultivators of your South had a little of his scientific and methodical spirit.

"Madame Pasteur joins with me in sending you and your family, dear master, the expression of my gratitude and affectionate devotion."

The normal season for the culture of silkworms was now approaching, and Pasteur was impatient to accumulate the proofs which would vouch for the safety of his method; this had been somewhat doubted by the members of the Lyons Silks Commission, who possessed an experimental nursery. Most of those gentlemen averred that too much confidence should not be placed in the micrographs. "Our Commission," thus ran their report of the preceding year, "considers the examination of corpuscles as a useful indication which should be consulted, but of which the results cannot be presented as a fact from which absolute consequences can be deducted."

"They *are* absolute," answered Pasteur, who did not admit reservations on a point which he considered as invulnerable.

On March 22, 1869, the Commission asked Pasteur for a little guaranteed healthy seed. Pasteur not only sent them this, but also sample lots, of which he thus predicted the future fate:—

1. One lot of healthy seed, which would succeed;

2. One lot of seed, which would perish exclusively from the corpuscle disease known as pébrine or gattine;

3. One lot of seed, which would perish exclusively from the flachery disease;

4. One lot of seeds, which would perish partly from corpuscle disease and partly from flachery.

"It seems to me," added Pasteur, "that the comparison between the results of those different lots will do more to enlighten the Commission on the certainty of the principles I have established than could a mere sample of healthy seed.

"I desire that this letter should be sent to the Commission at its next meeting, and put down in the minutes."

The Commission accepted with pleasure these unexpected surprise boxes.

About the same time one of his assistants, Maillot, started for Corsica at M. de Casabianca's request. He took with him six lots of healthy seed to Vescovato, a few miles from Bastia.

The rest of the colony returned to the Pont Gisquet, near Alais, that mulberry-planted retreat, where, according to Pasteur, everything was conducive to work. Pasteur now looked forward to his definitive victory, and, full of confidence, organized his pupils' missions. M. Du-

claux, who was coming to the Pont Gisquet to watch the normal broods, would afterwards go into the Cévennes to verify the seedings made on the selection system. M. Gernez was to note the results of some seedings made by Pasteur himself the preceding year at M. Raibaud-Lange's, at Paillerols, near Digne (Basses Alpes). Raulin alone would remain at the Pont Gisquet to study some points of detail concerning the flachery disease. So many results ought surely to reduce contradictors to silence!

"My dear friend and colleague," wrote Dumas to Pasteur, "I need not tell you with what anxiety we are watching the progress of your precious health and of your silkworm campaign. I shall certainly be at Alais at the end of the week, and I shall see, under your kind direction, all that may furnish me with the means of guiding public opinion. You have quacks to fight and envy to conquer, probably a hopeless task; the best is to march right through them, Truth leading the way. It is not likely that they will be converted or reduced to silence."

Whilst these expeditions were being planned, a letter from M. Gressier, the Minister of Agriculture, arrived very inopportunely. M. Gressier was better versed in *sub rosâ* ministerial combinations than in seeding processes, and he asked Pasteur to examine three lots of seeds sent to him by a Mademoiselle Amat, of Brives-la-Gaillarde,

who was celebrated in the department of the Corrèze for her good management of silk-worms. This *magnanarelle,* having had some successful results, was begging his Excellency to accord to those humble seeds his particular consideration, and to have them developed with every possible care.

At the same time she was sending samples of the same seeds to various places in the Gard, the Bouches du Rhône, etc., etc.

M. Gressier (April 20) asked Pasteur to examine them and to give him a detailed report. Pasteur answered four days afterwards in terms which were certainly not softened by the usual administrative precautions—

"Monsieur le Ministre, . . . these three sorts of seed are worthless. If they are developed, even in very small nurseries, they will in every instance succumb to corpuscle disease. If my seeding process had been employed, it would not have required ten minutes to discover that Mademoiselle Amat's cocoons, though excellent for spinning purposes, were absolutely unfit for reproduction. My seeding process gives the means of recognizing those broods which are suitable for seed, whilst opposing the production of the infected eggs which year by year flood the silkworm cultivating departments.

"I shall be much obliged, Monsieur le Ministre, if you will kindly inform the Prefect of the

Corrèze of the forecasts which I now impart to you, and if you will ask *him* to report to you the results of Mademoiselle Amat's three lots.

"For my part, I feel so sure of what I now affirm, that I shall not even trouble to test, by hatching them, the samples which you have sent me. I have thrown them into the river. . . ."

J. B. Dumas had come to Alais, Messrs. Gernez and Duclaux now returned from their expeditions. In two hundred broods, each of one or two ounces of seed, coming from three different sources and hatched in various localities, not one failure was recorded. The Lyons Commission, which had made a note of Pasteur's bold prognosis, found it absolutely correct; the excellence of the method was acknowledged by all who had conscientiously tried it. Now that the scourge was really conquered, Pasteur imagined that all he had to do was to set up a table of the results sent to him. But, from the south of France and from Corsica, jealousies were beginning their work of undermining; pseudo-scientists in their vanity proclaimed that everything was illusory that was outside their own affirmations, and the seed merchants, willing to ruin everybody rather than jeopardize their miserable interests, "did not hesitate (we are quoting M. Gernez) to perpetrate the most odious falsehoods."

Instead of being annoyed, saddened, often indignant as he was, Pasteur would have done more

wisely to look back upon the history of most great discoveries and of the initial difficulties which beset them. But he could not look upon such things philosophically; stupidity astonished him and he could not easily bring himself to believe in bad faith. His friends in Alais society, M. de Lachadenède, M. Despeyroux, professor of chemistry, might have reminded him, in their evening conversations, of the difficulties ever encountered in the service of mankind. The prejudice against potatoes, for instance, had lasted three hundred years. When they were brought over from Peru in the fifteenth century, it was asserted that they caused leprosy; in the seventeenth century, that accusation was recognized to be absurd, but it was said that they caused fever. One century later, in 1771, the Besançon Academy of Medicine having opened a competition for the answer to the following question of general interest: "What plants can be used to supplement other foods in times of famine?" a military apothecary, named Parmentier, competed and proved victoriously that the potato was quite harmless. After that, he began a propagandist campaign in favour of potatoes. But prejudice still subsisted in spite of his experimental fields and of the dinners in the menu of which potatoes held a large place. Louis XVI had then an inspiration worthy of Henry IV; he appeared in public, wearing in his buttonhole Parmentier's little mauve flower, and

thus glorified it in the eyes of the Court and of the crowd.

But such comparisons had no weight with Pasteur; he was henceforth sure of his method and longed to see it adopted, unable to understand why there should be further discussions now that the silkworm industry was saved and the bread of so many poor families assured. He was learning to know all the bitterness of sterile polemics, and the obstacles placed one by one in the way of those who attempt to give humanity anything new and useful. Fortunately he had what so many men of research have lacked, the active and zealous collaboration of pupils imbued with his principles, and the rarer and priceless blessing of a home life mingling with his laboratory life. His wife and his daughter, a mere child, shared his sericiculture labours; they had become *magnanarelles* equal to the most capable in Alais. Another privilege was the advocacy of some champions quite unknown to him. Those who loved science and who understood that it would now become, thanks to Pasteur, an important factor in agricultural and sericicultural matters hailed his achievements with joy.

. . . Marshal Vaillant began to take more and more interest in this question, which was not darkened, in his eyes at least, by the dust of polemics. The old soldier, always scrupulously punctual at the meetings of the Institute and of

the Imperial and Central Society of Agriculture, had amused himself by organizing a little silkworm nursery on the Pasteur system, in his own study, in the very centre of Paris. These experiments, in the Imperial palace might have reminded an erudite reader of Olivier de Serres' *Théâtre d'Agriculture* of the time when the said Olivier de Serres planted mulberry trees in the Tuileries gardens at Henry IV's request, and when, according to the old agricultural writer, a house was arranged at the end of the gardens "accommodated with all things necessary as well for the feeding of the worms as for the preparation of the silk."

The Marshal, though calling himself the most modest of sericicultors, had been able to appreciate the safety of a method which produced the same results in Paris as at the Pont Gisquet; the octogenarian veteran dwelt with complacency on the splendid condition of his silkworms in all their phases from the minute worm hatched from the seed-like egg to the splendid cocoon of white or yellow silk.

It occurred to Vaillant to suggest a decisive experiment in favour of Pasteur and of the silkworm industry. The Prince Imperial owned in Illyria, about six leagues from Trieste, a property called Villa Vicentina. One of Napoleon's sisters, Elisa Bonaparte, had lived peacefully there after the fall of the first Empire, and had

left it to her daughter, Princess Baciocchi, who bequeathed it to the Prince Imperial, with the rest of her fortune. Vines and mulberry trees grew plentifully on that vast domain, but the produce of cocoons was nil, pébrine and flachery having devastated the place. Marshal Vaillant, Minister of the Emperor's Household, desired to render the princely property once again productive and, at the same time, to give his colleague of the Institute an opportunity of "definitely silencing the opposition created by ignorance and jealousy." In a letter dated October 9, he requested Pasteur to send out 900 ounces of seed to Villa Vicentina, a large quantity, for one ounce produced, on an average, thirty kilogrammes of cocoons. Six days later the Marshal wrote to M. Tisserand, the director of the Crown agricultural establishments, who knew Villa Vicentina: "I have suggested to the Emperor that M. Pasteur should be offered a lodging at Villa Vicentina; the Emperor acquiesces in the most gracious manner. Tell me whether that is possible."

. . . Pasteur started three weeks later with his family; the long journey had to be taken in short stages, the state of his health still being very precarious. He stopped at Alais on the way, in order to fetch the selected seed, and on November 25, at 9 p.m., he reached Villa Vicentina. The fifty tenants of the domain did not suspect that the new arrival would bring back with

him the prosperity of former years. Raulin, the "temporizer," joined his master a few weeks later.

This was a period not of rest, but of a great calm, with regular work under a pure sky. Whilst waiting for hatching time, Pasteur continued to dictate to his wife the book he had mentioned to J. B. Dumas in a letter from St. Hippolyte le Fort. But the projected little book was changing its shape and growing into a two-volume work full of facts and documents. It was ready to publish by April, 1870.

When the moment for hatching the seed had arrived, Pasteur distributed twenty-five ounces among the tenants and kept twenty-five ounces for himself. An incident disturbed these days of work: a steward, who had by him an old box of Japanese seed, sold this suspicious seed with the rest. The idea that confiding peasants had thus been swindled sent Pasteur beside himself; in his violent anger he sent for this steward, overwhelmed him with reproaches and forbade him ever to show his face before him again.

"The Marshal," wrote Dumas to Pasteur, "has told me of the swindles you have come across and which have upset you so much. Do not worry unreasonably; if I were you I would merely insert a line in a local paper: 'M. Pasteur is only answerable for the seeds he himself sells to cultivators.' " Those cultivators soon were duly edi-

fied. The results of the seeding process were represented by a harvest of cocoons which brought in, after all expenses were paid, a profit of 22,000 francs, the first profit earned by the property for ten years. This was indeed an Imperial present from Pasteur; the Emperor was amazed and delighted.

RENÉ VALLERY-RADOT.

SOME REFLECTIONS UPON INSECT PSYCHOLOGY*

THE *laudator temporis acti* is out of favour just now: the world is on the move. Yes, but sometimes it moves backwards. When I was a boy, our twopenny textbooks told us that man was a reasoning animal; nowadays, there are learned volumes to prove to us that human reason is but a higher rung in the ladder whose foot reaches down to the bottommost depths of animal life. There is the greater and the lesser; there are all the intermediary rounds; but nowhere does it break off and start afresh. It begins with zero in the glair of a cell and ascends until we come to the mighty brain of a Newton. The noble faculty of which we were so proud is a zoological attribute. All have a larger or smaller share of it, from the live atom to the anthropoid ape, that hideous caricature of man.

It always struck me that those who held this levelling-theory made facts say more than they really meant; it struck me that, in order to obtain their plan, they were lowering the mountain-

*From "The Mason Bees" by permission of the publishers, Dodd, Mead, & Co.

peak of man, and elevating the valley, the animal. Now this levelling of theirs needed proofs, to my mind; and, as I found none in their books, or at any rate only doubtful and highly debatable ones, I did my own observing, in order to arrive at a definite conviction; I sought; I experimented.

To speak with any certainty, it behoves us not to go beyond what we really know. I am beginning to have a passable acquaintance with insects, after spending some forty years in their company. Let us question the insect, then: not the first that comes along, but the most gifted, the Hymenopteron. I am giving my opponents every advantage. Where will they find a creature more richly endowed with talent? It would seem as though, in creating it, nature had delighted in bestowing the greatest amount of industry upon the smallest body of matter. Can the bird, wonderful architect that it is, compare its work with that masterpiece of higher geometry, the edifice of the Bee? The Hymenopteron rivals man himself. We build towns, the Bee erects cities; we have servants, the Ant has hers; we rear domestic animals, she rears her sugar-yielding insects; we herd cattle, she herds her milch-cows, the Aphides; we have abolished slavery, whereas she continues her nigger-traffic.

Well, does this superior, this privileged being reason? Reader, do not smile: this is a most seri-

ous matter, well worthy of our consideration. To devote our attention to animals is to plunge at once into the vexed question of who we are and whence we come. What, then, passes in that little Hymenopteron brain? Has it faculties akin to ours, has it the power of thought? What a problem, if we could only solve it; what a chapter of psychology, if we could only write it! But, at our very first questionings, the mysterious will rise up, impenetrable: we may be convinced of that. We are incapable of knowing ourselves; what will it be if we try to fathom the intellect of others? Let us be content if we succeed in gleaning a few grains of truth.

What is reason? Philosophy would give us learned definitions. Let us be modest and keep to the simplest: we are only treating of animals. Reason is the faculty that connects the effect with its cause and directs the act by conforming it to the needs of the accidental. Within these limits, are animals capable of reasoning? Are they able to connect a "because" with a "why" and afterwards to regulate their behaviour accordingly? Are they able to change their line of conduct when faced with an emergency?

History has but few data likely to be of use to us here; and those which we find scattered in various authors are seldom able to withstand a severe examination. One of the most remarkable of which I know is supplied by Erasmus Darwin,

in his book entitled *Zoonomia*. It tells of a Wasp that has just caught and killed a big Fly. The wind is blowing, and the huntress, hampered in her flight by the great area presented by her prize, alights on the ground to amputate the abdomen, the head and the wings; she flies away, carrying with her only the thorax, which gives less hold to the wind. If we keep to the bald facts, this does, I admit, give a semblance of reason. The Wasp appears to grasp the relation between cause and effect. The effect is the resistance experienced in the flight; the cause is the dimensions of the prey contending with the air. Hence the logical conclusion: those dimensions must be decreased; the abdomen, the head and, above all, the wings must be chopped off; and the resistance will be lessened.*

*I would gladly, if I were able, cancel some rather hasty lines which I allowed myself to pen in the first volume of these *Souvenirs;* but *scripta manent* and all that I can do is to make amends now, in this note, for the error into which I fell. Relying on Lacordaire, who quotes this instance from Erasmus Darwin in his own *Introduction à l'entomologie,* I believed that a Sphex was given as the heroine of the story. How could I do otherwise, not having the original text in front of me? How could I suspect that an entomologist of Lacordaire's standing should be capable of such a blunder as to substitute a Sphex for a Common Wasp? Great was my perplexity, in the face of this evidence! A Sphex capturing a Fly was an impossibility; and I blamed the British scientist accordingly. But what insect was it that Erasmus Darwin saw? Calling logic to my aid, I declared

But does this concatenation of ideas, rudimentary though it be, really take place within the insect's brain? I am convinced of the contrary; and my proofs are unanswerable. In the first volume of these *Souvenirs*,* I demonstrated by experiment that Erasmus Darwin's Wasp was but obeying her instinct, which is to cut up the captured game and to keep only the most nourishing part, the thorax. Whether the day be perfectly calm or whether the wind blow, whether she be in the shelter of a dense thicket or in the open, I see the Wasp proceed to separate the succulent from the tough; I see her reject the legs, the wings, the head and the abdomen, retaining only the breast as pap for her larvæ. Then what value has this dissection as an argument in favour of the insect's reasoning-powers when the wind blows? It has no value at all, for it would take place just the same in absolutely calm weather. Erasmus Dar-

that it was a Wasp; and I could not have hit the mark more truly. Charles Darwin, in fact, informed me afterwards that his grandfather wrote, "a Wasp," in his *Zoonomia*. Though the correction did credit to my intelligence, I none the less deeply regretted my mistake, for I had uttered suspicions of the observer's powers of discernment, unjust suspicions which the translator's inaccuracy led me into entertaining. May this note serve to mitigate the harshness of the strictures provoked by my overtaxed credulity. I do not scruple to attack ideas which I consider false; but Heaven forfend that I should ever attack those who uphold them!—*Author's Note.*

* Cf. *Insect Life:* chap. ix.—*Translator's Note.*

win jumped too quickly to his conclusion, which was the outcome of his mental bias and not of the logic of things. If he had first enquired into the Wasp's habits, he would not have brought forward as a serious argument an incident which had no connection with the important question of animal reason.

I have reverted to this case to show the difficulties that beset the man who confines himself to casual observations, however carefully carried out. One should never rely upon a lucky chance, which may not occur again. We must multiply our observations, check them one with the other; we must create incidents, looking into preceding ones, finding out succeeding ones and working out the relation between them all: then and not till then, with extreme caution, are we entitled to express a few views worthy of credence. Nowhere do I find data collected under such conditions; for which reason, however much I might wish it, it is impossible for me to bring the evidence of others in support of the few conclusions which I myself have formed.

My Mason-bees, with their nests hanging on the walls of the arch which I have mentioned, lent themselves to continuous experiment better than any other Hymenopteron. I had them there, at my house, under my eyes, at all hours of the day, as long as I wished. I was free to follow their actions in full detail and to carry out suc-

cessfully any experiment, however long. Moreover, their numbers allowed me to repeat my attempts until I was perfectly convinced. The Mason-bees, therefore, shall supply me with materials for this chapter also.

A few words, before I begin, about the works. The Mason-bee of the Sheds utilizes, first of all, the old galleries of the clay nest, a part of which she good-naturedly abandons to two Osmiæ, her free tenants: the Three-horned Osmia and Latreille's Osmia. These old corridors, which save labour, are in great demand; but there are not many vacant, as the more precocious Osmiæ have already taken possession of most of them; and therefore the building of new cells soon begins. These cells are cemented to the surface of the nest, which thus increases in thickness every year. The edifice of cells is not built all at once: mortar and honey alternate repeatedly. The masonry starts with a sort of little swallow's nest, a half-cup or thimble, whose circumference is completed by the wall against which it rests. Picture the cup of an acorn cut in two and stuck to the surface of the nest: there you have the receptacle in a stage sufficiently advanced to take a first instalment of honey.

The Bee thereupon leaves the mortar and busies herself with harvesting. After a few foraging-trips, the work of building is resumed; and some new rows of bricks raise the edge of the

basin, which becomes capable of receiving a larger stock of provisions. Then comes another change of business: the mason once more becomes a harvester. A little later, the harvester is again a mason; and these alternations continue until the cell is of the regulation height and holds the amount of honey required for the larvæ. Thus come, turn and turn about, more or less numerous according to the occupation in hand, journeys to the dry and barren path, where the cement is gathered and mixed, and journeys to the flowers, where the Bee's crop is crammed with honey and her belly powdered with pollen.

At last comes the time for laying. We see the Bee arrive with a pellet of mortar. She gives a glance at the cell to enquire if everything is in order; she inserts her abdomen; and the egg is laid. Then and there the mother seals up the home: with her pellet of cement she closes the orifice and manages so well with the material that the lid receives its permanent form at this first sitting; it has only to be thickened and strengthened with fresh layers, a work which is less urgent and will be done by and by. What does appear to be an urgent necessity is the closing of the cell, immediately after the egg has been religiously deposited therein, so that there may be no danger from evilly-disposed visitors during the mother's absence.

The Bee must have serious reasons for thus

hurrying on the closing of the cell. What would happen if, after laying her egg, she left the house open and went to the cement-pit to fetch the wherewithal to block the door? Some thief might drop in and substitute her own egg for the Mason-bee's. We shall see that our suspicions are not uncalled-for. One thing is certain, that the Mason never lays without having in her mandibles the pellet of mortar required for the immediate construction of the lid of the nest. The precious egg must not for a single instant remain exposed to the cupidity of marauders.

To these particulars I will add a few general observations which will make what follows easier to understand. So long as its circumstances are normal, the insect's actions are calculated most rationally in view of the object to be attained. What could be more logical, for instance, than the devices employed by the Hunting-wasp when paralysing her prey * so that it may keep fresh for her larva, while in no wise imperilling that larva's safety? It is pre-eminently rational; we ourselves could think of nothing better; and yet the insect's action is not prompted by reason. If it thought out its surgery, it would be our superior. It will never occur to anybody that the creature is able, in the smallest degree, to account for its skilful vivisections. Therefore, so long

* Cf. *Insect Life:* chaps. iii. to xii. and xv. to xvii. —*Translator's Note.*

as it does not depart from the path mapped out for it, the insect can perform the most sagacious actions without entitling us in the least to attribute these to the dictates of reason.

What would happen in an emergency? Here we must distinguish carefully between two classes of emergency, or we shall be liable to grievous error. First, in accidents occurring in the course of the insect's occupation at the moment. In these circumstances, the creature is capable of remedying the accident; it continues, under a similar form, its actual task; it remains, in short, in the same psychic condition. In the second case, the accident is connected with a more remote occupation; it relates to a completed task with which, under normal conditions, the insect is no longer concerned. To meet this emergency, the creature would have to retrace its psychic course; it would have to do all over again what it has just finished, before turning its attention to anything else. Is the insect capable of this? Will it be able to leave the present and return to the past? Will it decide to hark back to a task that is much more pressing than the one on which it is engaged? If it did all this, then we should really have evidence of a modicum of reason. The question shall be settled by experiment.

We will begin by taking a few incidents that come under the first heading. A Mason-bee has finished the first layer of the covering of the

cell. She has gone in search of a second pellet of mortar wherewith to strengthen her work. In her absence, I prick the lid with a needle and widen the hole thus made, until it is half the size of the opening. The insect returns and repairs the damage. It was originally engaged on the lid and is merely continuing its work in mending that lid.

A second is still at her first row of bricks. The cell as yet is no more than a shallow cup, containing no provisions. I make a big hole in the bottom of the cup and the Bee hastens to stop the breach. She was busy building and turned aside a moment to do more building. Her repairs are the continuation of the work on which she was engaged.

A third has laid her egg and closed the cell. While she is gone in search of a fresh supply of cement to strengthen the door, I make a large aperture immediately below the lid, too high up to allow the honey to escape. The insect, on arriving with its mortar intended for a different task, sees its broken jar and soon puts the damage right. I have rarely witnessed such a sensible performance. Nevertheless, all things considered, let us not be too lavish of our praises. The insect was busy closing up. On its return, it sees a crack, representing in its eyes a bad joint which it had overlooked; it completes its actual task by improving the joint.

The conclusion to be drawn from these three instances, which I select from a large number of others, more or less similar, is that the insect is able to cope with emergencies, provided that the new action be not outside the course of its actual work at the moment. Shall we say then that reason directs it? Why should we? The insect persists in the same psychic course, it continues its action, it does what it was doing before, it corrects what to it appears but a careless flaw in the work of the moment.

Here, moreover, is something which would change our estimate entirely, if it ever occurred to us to look upon these repaired breaches as a work dictated by reason. Let us turn to the second class of emergency referred to above: let us imagine, first, cells similar to those in the second experiment, that is to say, only half-finished, in the form of a shallow cup, but already containing honey. I make a hole in the bottom, through which the provisions ooze and run to waste. Their owners are harvesting. Let us imagine, on the other hand, cells very nearly finished and almost completely provisioned. I perforate the bottom in the same way and let out the honey, which drips through gradually. The owners of these are building.

Judging by what has gone before, the reader will perhaps expect to see immediate repairs, urgent repairs, for the safety of the future larva

is at stake. Let him dismiss any such illusion: more and more journeys are undertaken, now in quest of food, now in quest of mortar; but not one of the Mason-bees troubles about the disastrous breach. The harvester goes on harvesting; the busy bricklayer proceeds with her next row of bricks, as though nothing out of the way had happened. Lastly, if the injured cells are high enough and contain enough provisions, the Bee lays her eggs, puts a door to the house and passes on to another house, without doing aught to remedy the leakage of the honey. Two or three days later, those cells have lost all their contents, which now form a long trail on the surface of the nest.

Is it through lack of intelligence that the Bee allows her honey to go to waste? May it not rather be through helplessness? It might happen that the sort of mortar which the mason has at her disposal will not set on the edges of a hole that is sticky with honey. The honey may prevent the cement from adjusting itself to the orifice, in which case the insect's inertness would merely be resignation to an irreparable evil. Let us look into the matter before drawing inferences. With my forceps, I deprive the Bee of her pellet of mortar and apply it to the hole whence the honey is escaping. My attempt at repairing meets with the fullest success, though I do not pretend to compete with the Mason in dex-

terity. For a piece of work done by a man's hand it is quite creditable. My dab of mortar fits nicely into the mutilated wall; it hardens as usual; and the escape of honey ceases. This is quite satisfactory. What would it be had the work been done by the insect, equipped with its tools of exquisite precision? When the Mason-bee refrains, therefore, this is not due to helplessness on her part, nor to any defect in the material employed.

Another objection presents itself. We are going too far perhaps in admitting this concatenation of ideas in the insect's mind, in expecting it to argue that the honey is running away because the cell has a hole in it and that to save it from being wasted the hole must be stopped. So much logic perhaps exceeds the powers of its poor little brain. Then, again, the hole is not seen; it is hidden by the honey trickling through. The cause of that stream of honey is an unknown cause; and to trace the loss of the liquid home to that cause, to the hole in the receptacle, is too lofty a piece of reasoning for the insect.

A cell in the rudimentary cup-stage and containing no provisions has a hole, three or four millimetres * wide, made in it at the bottom. A few moments later, this orifice is stopped by the Mason. We have already witnessed a similar patching. The insect, having finished, starts forag-

* .11 to .15 inch.—*Translator's Note.*

ing. I reopen the hole at the same place. The pollen runs through the aperture and falls to the ground as the Bee is rubbing off her first load in the cell. The damage is undoubtedly observed. When plunging her head into the cup to take stock of what she has stored, the Bee puts her antennæ into the artificial hole: she sounds it, she explores it, she cannot fail to perceive it.

I see the two feelers quivering outside the hole. The insect notices the breach in the wall: that is certain. It flies off. Will it bring back mortar from its present journey to repair the injured jar even as it did but a few minutes ago?

Not at all. It returns with provisions, it disgorges its honey, it rubs off its pollen, it mixes the material. The sticky and almost solid mass fills up the opening and oozes through with difficulty. I roll a spill of paper and free the hole, which remains open and shows daylight clearly in both directions. I sweep the place clear over and over again, whenever it becomes necessary because new provisions are brought; I clean the opening sometimes in the Bee's absence, sometimes in her presence, while she is busy mixing her paste. The unusual happenings in the warehouse plundered from below cannot escape her any more than the ever-open breach at the bottom of the cell. Nevertheless, for three consecutive hours, I witness this strange sight: the Bee, full of active zeal for the task in hand, omits to plug this vessel

of the Danaides. She persists in trying to fill her cracked receptacle, whence the provisions disappear as soon as stored away. She constantly alternates between mason's and harvester's work; she raises the edges of the cell with fresh rows of bricks; she brings provisions which I continue to abstract, so as to leave the breach always visible. She makes thirty-two journeys before my eyes, now for mortar, now for honey, and not once does she bethink herself of stopping the leakage at the bottom of her jar.

At five o'clock in the evening, the works cease. They are resumed on the morrow. This time, I neglect to clean out my artificial orifice and leave victuals gradually to ooze out by themselves. At length, the egg is laid and the door sealed up, without anything being done by the Bee in the matter of the disastrous breach. And yet to plug the hole were an easy matter for her: a pellet of her mortar would suffice. Besides, while the cup was still empty, did she not instantly close the hole which I had made? Why are not those early repairs of hers repeated? It clearly shows the creature's inability to retrace the course of its actions, however slightly. At the time of the first breach, the cup was empty and the insect was laying the first rows of bricks. The accident produced through my agency concerned that part of the work which occupied the Bee at the actual moment: it was a flaw in the build-

ing, such as can occur naturally in new courses of masonry, which have not had time to harden. In correcting that flaw, the mason did not go outside her usual work.

But, once the provisioning begins, the cup is finished for good and all; and, come what may, the insect will not touch it again. The harvester will go on harvesting, though the pollen trickle to the ground through the drain. To plug the hole would imply a change of occupation of which the insect is incapable for the moment. It is the honey's turn and not the mortar's. The rule upon this point is invariable. A moment comes, presently, when the harvesting is interrupted and the building resumed. The edifice must be raised a storey higher. Will the Bee, once more a mason, mixing fresh cement, now attend to the leakage at the bottom? No more than before. What occupies her at present is the new floor, whose brickwork would be repaired at once if it sustained a damage; but the bottom storey is too old a part of the business, it is ancient history; and the worker will not put a further touch to it, even though it be in serious danger.

For the rest, the present and the following storeys will all have the same fate. Carefully watched by the insect as long as they are in process of building, they are forgotten and allowed to go to ruin once they are

actually built. Here is a striking instance: in a cell which has attained its full height, I make a window, almost as large as the natural opening, and place it about half-way up, above the honey. The Bee brings provisions for some time longer and then lays her egg. Through my big window, I see the egg deposited on the victuals. The insect next works at the cover, to which it gives the finishing touches with a series of little taps, administered with infinite care, while the breach remains yawning. On the lid, it scrupulously stops up every pore that could admit so much as an atom; but it leaves the great opening that places the house at the mercy of the first-comer. It goes to that breach repeatedly, puts in its head, examines it, explores it with its antennæ, nibbles the edges of it. And that is all. The mutilated cell shall stay as it is, with never a dab of mortar. The threatened part dates too far back for the Bee to think of troubling about it.

I have said enough, I think, to show the insect's mental incapacity in the presence of the accidental. This incapacity is confirmed by renewing the test, an essential condition of all good experiments; therefore my notes are full of examples similar to the one which I have just described. To relate them would be mere repetition; I pass them over for the sake of brevity.

The renewal of a test is not sufficient: we

must also vary our test. Let us, then, examine the insect's intelligence from another point of view, that of the introduction of foreign bodies into the cell. The Mason-bee is a house-keeper of scrupulous cleanliness, as indeed are all Hymenoptera. Not a spot of dirt is permitted in her honey-pot; not a grain of dust is tolerated on the surface of her mixture. And yet, while the jar is open, the precious Bee-bread is exposed to accidents. The workers in the cells above may inadvertently drop a little mortar into the lower cells; the owner herself, when working at enlarging the jar, runs the risk of letting a speck of cement fall into the provisions. A Gnat, attracted by the smell, may come and be caught in the honey; brawls between neighbours who are getting into each other's way may send some dust flying thither. All this refuse has to disappear and that quickly, lest afterwards the larva should find coarse fare under its delicate mandibles. Therefore the Mason-bees must be able to cleanse the cell of any foreign body. And, in point of fact, they are well able to do so.

I place on the surface of the honey five or six bits of straw a millimetre * in length. Great astonishment on the part of the returning insect. Never before have so many sweepings accumulated in its warehouse. The Bee picks out the bits of straw, one by one, to the very last, and

* .039 inch.—*Translator's Note.*

each time goes and gets rid of them at a distance. The effort is out of all proportion to the work: I see the Bee soar above the nearest plane-tree, to a height of thirty feet, and fly away beyond it to rid herself of her burden, a mere atom. She fears lest she should litter the place by dropping her bit of straw on the ground, under the nest. A thing like that must be carried very far away.

I place upon the honey-paste a Mason-bee's egg which I myself saw laid in an adjacent cell. The Bee picks it out and goes and throws it away at a distance, like the straws just now. There are two inferences to be drawn from this, both extremely interesting. In the first place, that precious egg, for whose future the Bee labours so indefatigably, becomes a valueless, cumbersome, hateful thing when it belongs to another. Her own egg is everything; the egg of her next-door neighbour is nothing. It is flung on the dust-heap like any bit of rubbish. The individual, so zealous on behalf of her family, displays an abominable indifference for the rest of her kind. Each one for himself. In the second place, I ask myself, without as yet being able to find an answer to my question, how certain parasites go to work to give their larva the benefit of the provisions accumulated by the Mason-bee. If they decide to lay their egg on the victuals of the open cell, the Bee, when she sees it, will

not fail to cast it out; if they decide to lay after the owner, they cannot do so, for she blocks up the door as soon as her laying is done. This curious problem must be reserved for future investigation.*

Lastly, I stick into the paste a bit of straw nearly an inch long and standing well out above the rim of the cell. The insect extracts it by dint of great efforts, dragging it away from one side; or else, with the help of its wings, it drags it from above. It darts away with the honey-smeared straw and gets rid of it at a distance, after flying over the plane-tree.

This is where things begin to get complicated. I have said that, when the time comes for laying, the Mason-bee arrives with a pellet of mortar wherewith immediately to make a door to the house. The insect with its front legs resting on the rim, inserts its abdomen in the cell; it has the mortar ready in its mouth. Having laid the egg, it comes out and turns round to block the door. I wave it away for a second, at the same time planting my straw as before, a straw sticking out for nearly a centimetre.† What will the Bee do? Will she, who is scrupulous in ridding the home of the least mote of dust, extract this

* Cf. *The Life of the Fly:* chaps. ii. to iv.; and several later chapters in the present volume.—*Translator's Note.*

† .39 inch.—*Translator's Note.*

beam, which would certainly prove the larva's undoing by interfering with its growth? She could, for just now we saw her drag out and throw away, at a distance, a similar beam.

She could and she doesn't. She closes the cell, cements the lid, seals up the straw in the thickness of the mortar. More journeys are taken, not a few, in search of the cement required to strengthen the cover. Each time, the mason applies the material with the most minute care, while giving the straw not a thought. In this way, I obtain, one after the other, eight closed cells whose lids are surmounted by my mast, a bit of protruding straw. What evidence of obtuse intelligence!

This result is deserving of attentive consideration. At the moment when I am inserting my beam, the insect has its mandibles engaged: they are holding the pellet of mortar intended for the blocking-operation. As the extracting-tool is not free, the extraction does not take place. I expected to see the Bee relinquish her mortar and then proceed to remove the encumbrance. A dab of mortar more or less is not a serious business. I had already noticed that it takes my Mason-bees a journey of three or four minutes to collect one. The pollen-expeditions last longer, a matter of ten or fifteen minutes. To drop her pellet, grab the straw with her mandibles, now disengaged, remove it and gather a fresh supply

of cement would entail a loss of five minutes at most. The Bee decides differently. She will not, she cannot relinquish her pellet; and she uses it. No matter that the larva will perish by this untimely trowelling: the moment has come to wall up the door; the door is walled up. Once the mandibles are free, the extraction could be attempted, at the risk of wrecking the lid. But the Bee does nothing of the sort: she keeps on fetching mortar; and the lid is religiously finished.

We might go on to say that, if the Bee were obliged to depart in quest of fresh mortar after dropping the first to withdraw the straw, she would leave the egg unguarded; and that this would be an extreme measure which the mother cannot bring herself to adopt. Then why does she not place the pellet on the rim of the cell? The mandibles, now free, would remove the beam; the pellet would be taken up again at once; and everything would go to perfection. But no: the insect has its mortar and, come what may, employs it on the work for which it was intended.

If any one sees a rudiment of reason in this Hymenopteron intelligence, he has eyes that are more penetrating than mine. I see nothing in all this but an invincible persistence in the act once begun. The cogs have gripped; and the rest of the wheels must follow. The mandibles are

fastened on the pellet of mortar; and the idea, the wish to unfasten them will never occur to the insect until the pellet has fulfilled its purpose. And here is a still greater absurdity: the plugging once begun is very carefully finished with fresh relays of mortar! Exquisite attention is paid to a closing-up which is henceforth useless; no attention at all to the dangerous beam. O little gleams of reason that are said to enlighten the animal, you are very near the darkness, you are naught!

Another and still more eloquent fact will finally convince whoso may yet be doubting. The ration of honey stored up in a cell is evidently measured by the needs of the coming larva. There is neither too much nor too little. How does the Bee know when the proper quantity is reached? The cells are more or less constant in dimension, but they are not filled completely, only to about two-thirds of their height. A large space is therefore left empty; and the victualler has to judge of the moment when the surface of the mess has attained the right level. The honey being perfectly opaque, its depth is not apparent. I have to use a sounding-rod, when I want to gauge the contents of the jar; and I find, on the average, that the honey reaches a depth of ten millimetres.* The Bee has not this resource; she has sight, which may enable her to

* .39 inch.—*Translator's Note.*

estimate the full section from the empty section. This presupposes the possession of a somewhat geometric eye, capable of measuring the third of a distance. If the insect did it by Euclid, that would be very brilliant of it. What a magnificent proof in favour of its little intellect: a Chalicodoma with a geometrician's eye, able to divide a straight line into three equal parts! This is worth looking into seriously.

I take five cells, which are only partly provisioned, and empty them of their honey with a wad of cotton held in my forceps. From time to time, as the Bee brings new provisions, I repeat the cleansing-process, sometimes clearing out the cell entirely, sometimes leaving a thin layer at the bottom. I do not observe any pronounced hesitation on the part of my plundered victims, even though they surprise me at the moment when I am draining the jar; they continue their work with quiet industry. Sometimes, two or three threads of cotton remain clinging to the walls of the cells: the Bees remove them carefully and dart away to a distance, as usual, to get rid of them. At last, a little sooner or a little later, the egg is laid and the lid fastened on.

I break open the five closed cells. In one, the egg has been laid on three millimetres of honey;* in two, on one millimetre;† and, in the two

* .117 inch.—*Translator's Note.*
† .039 inch.—*Translator's Note.*

others, it is placed on the side of the receptacle drained of all its contents, or, to be more accurate, having only the glaze, the varnish left by the friction of the honey-covered cotton.

The inference is obvious: the Bee does not judge of the quantity of honey by the elevation of the surface; she does not reason like a geometrician, she does not reason at all. She accumulates so long as she feels within her the secret impulse that prompts her to go on collecting until the victualling is completed; she ceases to accumulate when that impulse is satisfied, irrespective of the result, which in this case happen to be worthless. No mental faculty, assisted by sight, informs her when she has enough, when she has too little. An instinctive predisposition is her only guide, an infallible guide under normal conditions, but hopelessly lost when subjected to the wiles of the experimenter. Had the Bee the least glimmer of reason, would she lay her egg on the third, on the tenth part of the necessary provender? Would she lay it in an empty cell? Would she be guilty of such inconceivable maternal aberration as to leave her nurseling without nourishment? I have told the story; let the reader decide.

This instinctive predisposition, which does not leave the insect free to act and, through that very fact, saves it from error, bursts forth under yet another aspect. Let us grant the Bee as much

judgment as you please. Thus endowed, will she be capable of meting out the future larva's portion? By no means. The Bee does not know what that portion is. There is nothing to tell the materfamilias; and yet, at her first attempt, she fills the honey-pot to the requisite depth. True, in her childhood, she received a similar ration but she consumed it in the darkness of a cell; and, besides, as a grub, she was blind. Sight was not her informant: it did not tell her the quantity of the provisions. Did memory, the memory of the stomach that once digested them? But digestion took place a year ago; and, since that distant epoch, the nurseling, now an adult insect, has changed its shape, its dwelling, its mode of life. It was a grub; it is a Bee. Does the actual insect remember that childhood's meal? No more than we remember the sups of milk drawn from our mother's breast. The Bee, therefore, knows nothing of the quantity of provisions needed by her larva, whether from memory, from example or from acquired experience. Then what guides her when she makes her estimate with such precision? Judgment and sight would leave the mother greatly perplexed, liable to provide too much or not enough. To instruct her beyond the possibility of a mistake demands a special tendency, an unconscious impulse, an instinct, an inward voice that dictates the measure to be apportioned.

JEAN HENRI FABRE.

THE POND IN WINTER

AFTER a still winter night I awoke with the impression that some question had been put to me, which I had been endeavouring in vain to answer in my sleep, as what—how—when—where? But there was dawning Nature, in whom all creatures live, looking in at my broad windows with serene and satisfied face, and no question on *her* lips. I awoke to an answered question, to Nature and daylight. The snow lying deep on the earth dotted with young pines, and the very slope of the hill on which my house is placed seemed to say, Forward! Nature puts no question, and answers none which we mortals ask. She has long ago taken her resolution. "O Prince, our eyes contemplate with admiration and transmit to the soul the wonderful and varied spectacle of this universe. The night veils without doubt a part of this glorious creation; but day comes to reveal to us this great work, which extends from earth even into the plains of the ether."

Then to my morning work. First I take an axe and pail and go in search of water, if that be not a dream. After a cold and snowy night

it needed a divining rod to find it. Every winter the liquid and trembling surface of the pond, which was so sensitive to every breath, and reflected every light and shadow, becomes solid to the depth of a foot or a foot and a half, so that it will support the heaviest teams, and perchance the snow covers it to an equal depth, and it is not to be distinguished from any level field. Like the marmots in the surrounding hills, it closes its eyelids and becomes dormant for three months or more. Standing on the snow-covered plain, as if in a pasture amid the hills, I cut my way first through a foot of snow, and then a foot of ice, and open a window under my feet, where, kneeling to drink, I look down into the quiet parlour of the fishes, pervaded by a softened light as through a window of ground glass, with its bright sanded floor the same as in summer; there a perennial waveless serenity reigns as in the amber twilight sky, corresponding to the cool and even temperament of the inhabitants. Heaven is under our feet as well as over our heads.

Early in the morning, while all things are crisp with frost, men come with fishing reels and slender lunch, and let down their fine lines through the snowy field to take pickerel and perch; wild men, who instinctively follow other fashions and trust other authorities than their townsmen, and by their goings and comings stitch

towns together in parts where else they would be ripped. They sit and eat their luncheon in stout fear-naughts on the dry oak leaves on the shore, as wise in natural lore as the citizen is in artificial. They never consulted with books, and know and can tell much less than they have done. The things which they practise are said not yet to be known. Here is one fishing for pickerel with grown perch for bait. You look into his pail with wonder as into a summer pond, as if he kept summer locked up at home, or knew where she had retreated. How, pray, did he get these in mid-winter? Oh, he got worms out of rotten logs since the ground froze, and so he caught them. His life itself passes deeper in Nature than the studies of the naturalist penetrate, himself a subject for the naturalist. The latter raises the moss and bark gently with his knife in search of insects; the former lays open logs to their core with his axe, and moss and bark fly far and wide. He gets his living by barking trees. Such a man has some right to fish, and I love to see Nature carried out in him. The perch swallows the grub-worm, the pickerel swallows the perch, and the fisherman swallows the pickerel; and so all the chinks in the scale of being are filled.

When I strolled around the pond in misty weather I was sometimes amused by the primitive mode which some ruder fisherman had

adopted. He would perhaps have placed alder branches over the narrow holes in the ice, which were four or five rods apart and an equal distance from the shore, and having fastened the end of the line to a stick to prevent its being pulled through, have passed the slack line over a twig of the alder, a foot or more above the ice, and tied a dry oak leaf to it, which, being pulled down, would show when he had a bite. These alders loomed through the mist at regular intervals as you walked half-way round the pond.

Ah, the pickerel of Walden! when I see them lying on the ice, or in the well which the fisherman cuts in the ice, making a little hole to admit the water, I am always surprised by their rare beauty, as if they were fabulous fishes, they are so foreign to the streets, even to the woods, foreign as Arabia to our Concord life. They possess a quite dazzling and transcendent beauty, which separates them by a wide interval from the cadaverous cod and haddock whose fame is trumpeted in our streets. They are not green like the pines, nor grey like the stones, nor blue like the sky; but they have, to my eyes, if possible, yet rarer colours, like flowers and precious stones, as if they were the pearls, the animalized *nuclei* or crystals of the Walden water. They, of course, are Walden all over and all through; are themselves small Waldens in the animal kingdom, Waldenses. It is surprising that they

are caught here,—that in this deep and capacious spring, far beneath the rattling teams and chaises and tinkling sleighs that travel the Walden road, this great gold and emerald fish swims. I never chanced to see its kind in any market; it would be the cynosure of all eyes there. Easily, with a few convulsive quirks, they give up their watery ghosts, like a mortal translated before his time to the thin air of heaven.

As I was desirous to recover the long lost bottom of Walden Pond, I surveyed it carefully, before the ice broke up, early in '46, with compass and chain and sounding line. There have been many stories told about the bottom, or rather no bottom, of this pond, which certainly had no foundation for themselves. It is remarkable how long men will believe in the bottomlessness of a pond without taking the trouble to sound it. I have visited two such Bottomless Ponds in one walk in this neighbourhood. Many have believed that Walden reached quite through to the other side of the globe. Some who have lain flat on the ice for a long time, looking down through the illusive medium, perchance with watery eyes into the bargain, and driven to hasty conclusions by the fear of catching cold in their breasts, have seen vast holes "into which a load of hay might be driven," if there were anybody to drive it, the undoubted source of

the Styx and entrance to the Infernal Regions from these parts. Others have gone down from the village with a "fifty-six" and a waggon load of inch rope, but yet have failed to find any bottom; for while the "fifty-six" was resting by the way, they were paying out the rope in the vain attempt to fathom their truly immeasurable capacity for marvellousness. But I can assure my readers that Walden has a reasonably tight bottom at a not unreasonable, though at an unusual depth. I fathomed it easily with a cod-line and a stone weighing about a pound and a-half, and could tell accurately when the stone left the bottom, by having to pull so much harder before the water got underneath to help me. The greatest depth was exactly one hundred and two feet; to which may be added the five feet which it has risen since, making one hundred and seven. This is a remarkable depth for so small an area; yet not an inch of it can be spared by the imagination. What if all ponds were shallow? Would it not react on the minds of men? I am thankful that this pond was made deep and pure for a symbol. While men believe in the infinite, some ponds will be thought to be bottomless.

A factory owner, hearing what depth I had found, thought it could not be true, for, judging from his acquaintance with dams, sand would not lie at so steep an angle. But the deepest

ponds are not so deep in proportion to their area as most suppose, and, if drained, would not leave very remarkable valleys. They are not like cups between the hills; for this one, which is so unusually deep for its area, appears in a vertical section through its centre not deeper than a shallow plate. Most ponds, emptied, would leave a meadow no more hollow than we frequently see. William Gilpin, who is so admirable in all that relates to landscapes, and usually so correct, standing at the head of Loch Fyne, in Scotland, which he describes as "a bay of salt water, sixty or seventy fathoms deep, four miles in breadth," and about fifty miles long, surrounded by mountains, observes, "if we could have seen it immediately after the diluvian crash, or whatever convulsion of Nature occasioned it, before the waters gushed in, what a horrid chasm it must have appeared!

" 'So high as heaved the tumid hills, so low
Down sunk a hollow bottom, broad, and deep,
Capacious bed of waters.—' "

But if, using the shortest diameter of Loch Fyne, we apply these proportions to Walden, which, as we have seen, appears already in a vertical section only like a shallow plate, it will appear four times as shallow. So much for the *increased* horrors of the chasm of Loch Fyne when emptied. No doubt many a smiling valley with its stretch-

ing corn-fields occupies exactly such a "horrid chasm," from which the waters have receded, though it requires the insight and the far sight of the geologist to convince the unsuspecting inhabitants of this fact. Often an inquisitive eye may detect the shores of a primitive lake in the low horizon hills, and no subsequent elevation of the plain have been necessary to conceal their history. But it is easiest, as they who work on the highways know, to find the hollows by the puddles after a shower. The amount of it is, the imagination, give it the least license, dives deeper and soars higher than Nature goes. So, probably, the depth of the ocean will be found to be very inconsiderable compared with its breadth.

As I sounded through the ice I could determine the shape of the bottom with greater accuracy than is possible in surveying harbours which do not freeze over, and I was surprised at its general regularity. In the deepest part there are several acres more level than almost any field which is exposed to the sun, wind, and plough. In one instance, on a line arbitrarily chosen, the depth did not vary more than one foot in thirty rods; and generally, near the middle, I could calculate the variation of each one hundred feet in any direction beforehand within three or four inches. Some are accustomed to speak of deep and dangerous holes even in quiet

sandy ponds like this, but the effect of water under these circumstances is to level all inequalities. The regularity of the bottom and its comformity to the shores and the range of the neighbouring hills were so perfect that a distant promontory betrayed itself in the soundings quite across the pond, and its direction could be determined by observing the opposite shore. Cape becomes bar, and plain shoal, and valley and gorge deep water and channel.

When I had mapped the pond by the scale of ten rods to an inch, and put down the soundings, more than a hundred in all, I observed this remarkable coincidence. Having noticed that the number indicating the greatest depth was apparently in the centre of the map, I laid a rule on the map lengthwise, and then breadthwise, and found, to my surprise, that the line of greatest length intersected the line of greatest breadth *exactly* at the point of the greatest depth, notwithstanding that the middle is so nearly level, the outline of the pond far from regular, and the extreme length and breadth were got by measuring into the coves; and I said to myself, Who knows but this hint would conduct to the deepest part of the ocean as well as of a pond or puddle? Is not this the rule also for the height of mountains, regarded as the opposite of valleys? We know that a hill is not highest at its narrowest part.

Of five coves, three, or all which had been sounded, were observed to have a bar quite across their mouths and deeper water within, so that the bay tended to be an expansion of water within the land not only horizontally but vertically, and to form a basin or independent pond, the direction of the two capes showing the course of the bar. Every harbour on the sea-coast, also, has its bar at its entrance. In proportion as the mouth of the cove was wider compared with its length, the water over the bar was deeper compared with that in the basin. Given, then, the length and breadth of the cove, and the character of the surrounding shore, and you have almost elements enough to make out a formula for all cases.

In order to see how nearly I could guess, with this experience, at the deepest point in a pond, by observing the outlines of its surface and the character of its shores alone, I made a plan of White Pond, which contains about forty-one acres, and, like this, has no island in it, nor any visible inlet or outlet; and as the line of greatest breadth fell very near the line of least breadth, where two opposite capes approached each other and two opposite bays receded, I ventured to mark a point a short distance from the latter line, but still on the line of greatest length, as the deepest. The deepest part was found to be within one hundred feet of this, still farther in

the direction to which I had inclined, and was only one foot deeper, namely, sixty feet. Of course a stream running through, or an island in the pond, would make the problem much more complicated.

If we knew all the laws of Nature, we should need only one fact, or the description of one actual phenomenon, to infer all the particular results at that point. Now we know only a few laws, and our result is vitiated, not, of course, by any confusion or irregularity in Nature, but by our ignorance of essential elements in the calculation. Our notions of law and harmony are commonly confined to those instances which we detect; but the harmony which results from a far greater number of seemingly conflicting, but really concurring, laws, which we have not detected, is still more wonderful. The particular laws are as our points of view, as, to the traveller, a mountain outline varies with every step, and it has an infinite number of profiles, though absolutely but one form. Even when cleft or bored through it is not comprehended in its entireness.

What I have observed of the pond is no less true in ethics. It is the law of average. Such a rule of the two diameters not only guides us toward the sun in the system and the heart in man, but draw lines through the length and breadth of the aggregate of a man's particular

daily behaviours and waves of life into his coves and inlets, and where they intersect will be the height or depth of his character. Perhaps we need only to know how his shores trend and his adjacent country or circumstances, to infer his depth and concealed bottom. If he is surrounded by mountainous circumstances, an Achillean shore, whose peaks overshadow and are reflected in his bosom, they suggest a corresponding depth in him. But a low and smooth shore proves him shallow on that side. In our bodies, a bold projecting brow falls off to and indicates a corresponding depth of thought. Also there is a bar across the entrance of our every cove, or particular inclination; each is our harbour for a season, in which we are detained and partially land-locked. These inclinations are not whimsical usually, but their form, size, and direction are determined by the promontories of the shore, the ancient axis of elevation. When this bar is gradually increased by storms, tides, or currents, or there is a subsidence of the waters, so that it reaches to the surface, that which was at first but an inclination in the shore in which a thought was harboured becomes an individual lake, cut off from the ocean, wherein the thought secures its own conditions, changes, perhaps, from salt to fresh, becomes a sweet sea, dead sea, or a marsh. At the advent of each individual into this life, may we not suppose that such a bar

has risen to the surface somewhere? It is true, we are such poor navigators that our thoughts, for the most part, stand off and on upon a harbourless coast, are conversant only with the bights of the bays of poesy, or steer for the public ports of entry, and go into the dry docks of science, where they merely refit for this world, and no natural currents concur to individualize them.

As for the inlet or outlet of Walden, I have not discovered any but rain and snow and evaporation, though perhaps, with a thermometer and a line, such places may be found, for where water flows into the pond it will probably be coldest in summer and warmest in winter. When the icemen were at work here in '46–7, the cakes sent to the shore were one day rejected by those who were stacking them up there, not being thick enough to lie side by side with the rest; and the cutters thus discovered that the ice over a small space was two or three inches thinner than elsewhere, which made them think that there was an inlet there. They also showed me in another place what they thought was a "leach hole," through which the pond leaked out under a hill into a neighbouring meadow, pushing me out on a cake of ice to see it. It was a small cavity under ten feet of water; but I think that I can warrant the pond not to need soldering till they find a worse leak than that. One has

suggested that if such a "leach hole" should be found, its connection with the meadow might be proved by conveying some coloured powder or sawdust to the mouth of the hole, and then putting a strainer over the spring in the meadow, which would catch some of the particles carried through by the current.

While I was surveying, the ice, which was sixteen inches thick, undulated under a slight wind like water. It is well known that a level cannot be used on ice. At one rod from the shore its greatest fluctuation, when observed by means of a level on land directed toward a graduated staff on the ice, was three-quarters of an inch, though the ice appeared firmly attached to the shore. It was probably greater in the middle. Who knows but if our instruments were delicate enough we might detect an undulation in the crust of the earth? When two legs of my level were on the shore and the third on the ice, and the sights were directed over the latter, a rise or fall of the ice of an almost infinitesimal amount made a difference of several feet on a tree across the pond. When I began to cut holes for sounding, there were three or four inches of water on the ice under a deep snow which had sunk it thus far; but the water began immediately to run into these holes, and continued to run for two days in deep streams, which wore away the ice on every side, and contributed

essentially, if not mainly, to dry the surface of the pond; for, as the water ran in, it raised and floated the ice. This was somewhat like cutting a hole in the bottom of a ship to let the water out. When such holes freeze, and a rain succeeds, and finally a new freezing forms a fresh smooth ice over all, it is beautifully mottled internally by dark figures, shaped somewhat like a spider's web, what you may call ice rosettes, produced by the channels worn by the water flowing from all sides to a centre. Sometimes, also, when the ice was covered with shallow puddles, I saw a double shadow of myself, one standing on the head of the other—one on the ice, the other on the trees or hill-side.

While yet it is cold January, and snow and ice are thick and solid, the prudent landlord comes from the village to get ice to cool his summer drink; impressively, even pathetically wise, to foresee the heat and thirst of July now in January,—wearing a thick coat and mittens! when so many things are not provided for. It may be that he lays up no treasures in this world which will cool his summer drink in the next. He cuts and saws the solid pond, unroofs the house of fishes, and carts off their very element and air, held fast by chains and stakes like corded wood through the favouring winter air, to wintry cellars, to underlie the summer there.

It looks like solidified azure, as, far off, it is drawn through the streets. These ice-cutters are a merry race, full of jest and sport, and when I went among them they were wont to invite me to saw pit-fashion with them, I standing underneath.

In the winter of '46–7 there came a hundred men of Hyperborean extraction swoop down on to our pond one morning, with many car-loads of ungainly-looking farming tools, sleds, ploughs, drill-barrows, turf-knives, spades, saws, rakes, and each man was armed with a double-pointed pike-staff, such as is not described in the "New England Farmer" or the "Cultivator." I did not know whether they had come to sow a crop of winter rye, or some other kind of grain recently introduced from Iceland. As I saw no manure, I judged that they meant to skim the land, as I had done, thinking the soil was deep and had lain fallow long enough. They said that a gentleman farmer, who was behind the scenes, wanted to double his money, which, as I understood, amounted to half a million already; but in order to cover each one of his dollars with another, he took off the only coat, ay, the skin itself, of Walden Pond in the midst of a hard winter. They went to work at once, ploughing, harrowing, rolling, furrowing, in admirable order, as if they were bent on making this a model farm; but when I was looking sharp to see

what kind of seed they dropped into the furrow, a gang of fellows by my side suddenly began to hook up the virgin mould itself, with a peculiar jerk, clean down to the sand, or rather the water,—for it was a very springy soil,—indeed all the *terra firma* there was,—and haul it away on sleds, and then I guessed that they must be cutting peat in a bog. So they came and went every day, with a peculiar shriek from the locomotive, from and to some point of the polar regions, as it seemed to me, like a flock of arctic snow-birds. But sometimes Squaw Walden had her revenge, and a hired man, walking behind his team, slipped through a crack in the ground down toward Tartarus, and he who was so brave before suddenly became but the ninth part of a man, almost gave up his animal heat, and was glad to take refuge in my house, and acknowledged that there was some virtue in a stove; or sometimes the frozen soil took a piece of steel out of a ploughshare, or a plough got set in the furrow and had to be cut out.

To speak literally, a hundred Irishmen, with Yankee overseers, came from Cambridge every day to get out the ice. They divided it into cakes by methods too well known to require description, and these, being sledded to the shore, were rapidly hauled off on to an ice platform, and raised by grappling irons and block and tackle, worked by horses, on to a stack, as surely

as so many barrels of flour, and there placed evenly side by side, and row upon row, as if they formed the solid base of an obelisk designed to pierce the clouds. They told me that in a good day they could get out a thousand tons, which was the yield of about one acre. Deep ruts and "cradle holes" were worn in the ice, as on *terra firma,* by the passage of the sleds over the same track, and the horses invariably ate their oats out of cakes of ice hollowed out like buckets. They stacked up the cakes thus in the open air in a pile thirty-five feet high on one side and six or seven rods square, putting hay between the outside layers to exclude the air; for when the wind, though never so cold, finds a passage through, it will wear large cavities, leaving slight supports or studs only here and there, and finally topple it down. At first it looked like a vast blue fort or Valhalla; but when they began to tuck the coarse meadow hay into the crevices, and this became covered with rime and icicles, it looked like a venerable moss-grown and hoary ruin, built of azure-tinted marble, the abode of Winter, that old man we see in the almanac—his shanty, as if he had a design to estivate with us. They calculated that not twenty-five per cent. of this would reach its destination, and that two or three per cent. would be wasted in the cars. However, a still greater part of this heap had a different destiny from what was intended; for,

either because the ice was found not to keep so well as was expected, containing more air than usual, or for some other reason, it never got to market. This heap, made in the winter of '46–7, and estimated to contain ten thousand tons, was finally covered with hay and boards; and though it was unroofed the following July, and a part of it carried off, the rest remaining exposed to the sun, it stood over that summer and the next winter, and was not quite melted till September 1848. Thus the pond recovered the greater part.

Like the water, the Walden ice, seen near at hand, has a green tint, but at a distance is beautifully blue, and you can easily tell it from the white ice of the river or the merely greenish ice of some ponds, a quarter of a mile off. Sometimes one of those great cakes slips from the ice-man's sled into the village street, and lies there for a week like a great emerald, an object of interest to all passers. I have noticed that a portion of Walden which in the state of water was green, will often, when frozen, appear from the same point of view blue. So the hollows about this pond will, sometimes, in the winter, be filled with a greenish water somewhat like its own, but the next day will have frozen blue. Perhaps the blue colour of water and ice is due to the light and air they contain, and the most transparent is the bluest. Ice is an interesting subject for con-

temptation. They told me that they had some in the ice-houses at Fresh Pond five years old which was as good as ever. Why is it that a bucket of water soon becomes putrid, but frozen remains sweet for ever? It is commonly said that this is the difference between the affections and the intellect.

Thus for sixteen days I saw from my window a hundred men at work like busy husbandmen, with teams and horses and apparently all the implements of farming, such a picture as we see on the first page of the almanac; and as often as I looked out I was reminded of the fable of the lark and the reapers, or the parable of the sower, and the like; and now they are all gone; and in thirty days more, probably, I shall look from the same window on the pure sea-green Walden water there, reflecting the clouds and the trees, and sending up its evaporations in solitude, and no traces will appear that a man has ever stood there. Perhaps I shall hear a solitary loon laugh as he dives and plumes himself, or shall see a lonely fisher in his boat, like a floating leaf, beholding his form reflected in the waves, where lately a hundred men securely laboured.

Thus it appears that the sweltering inhabitants of Charleston and New Orleans, of Madras and Bombay and Calcutta, drink at my well. In the morning I bathe my intellect in the stupendous

and cosmogonal philosophy of the Bhagvat Geeta, since whose composition years of the gods have elapsed, and in comparison with which our modern world and its literature seem puny and trivial; and I doubt if that philosophy is not to be referred to a previous state of existence, so remote is its sublimity from our conceptions. I lay down the book and go to my well for water, and lo! there I meet the servant of the Brahmin, priest of Brahma and Vishnu and Indra, who still sits in his temple on the Ganges reading the Vedas, or dwells at the root of a tree with his crust and water-jug. I meet his servant come to draw water for his master, and our buckets, as it were, grate together in the same well. The pure Walden water is mingled with the sacred water of the Ganges. With favouring winds it is wafted past the site of the fabulous islands of Atlantis and the Hesperides, makes the periplus of Hanno, and, floating by Ternate and Tidore, and the mouth of the Persian Gulf, melts in the tropic gales of the Indian seas, and is landed in ports of which Alexander only heard the names.

HENRY DAVID THOREAU.

THE END